VOL. 12, NO. 3 September, 1937

THE QUARTERLY REVIEW
of BIOLOGY

THE NATURE OF ORGANIC WHOLENESS

By FRANCIS G. GILCHRIST

I

WE HAVE become so accustomed to building toy houses of blocks, or constructing automobiles from accurately machined parts, that we think of wholes as formed by putting pieces together. It comes therefore as somewhat of a struggle to picture to ourselves a process, such as the molding of a vase from a lump of clay, in which the whole precedes the parts and gives to the parts their meaning. Yet it is this latter analogy and not the former which we must have in mind if we are to comprehend aright the nature of the organism and the processes of its becoming.

If one would understand a machine he will take it apart, either actually or in his imagination, and will study it piece by piece, noting the characteristics of each piece and the relations of each piece to each other piece. Then by synthesizing the knowledge thus obtained, he will understand the machine. On the other hand, if one would understand the vase or organism, he must begin by first comprehending the thing as a whole. Only then will he be able to discern the significance of the parts. Indeed, he may fail to discern discrete parts at all; yet his appreciation of the whole will not thereby be impaired.

But how does one comprehend a whole except by knowing the parts and observing their relations to one another? Can one know a whole directly? Yes. Indeed, it is the natural thing to do. The child knows a cat before it distinguishes a head. It knows its mother's face before it discerns her eyes. It would be very unnatural indeed for a child to reconstruct its concept of a face by piecing together its various anatomical structures or its characters. It is just as unnatural for a biologist to construct his concept of an organism by adding together entities of any sort, be they organs, germ layers, unit characters, cleavage cells, or organ-forming stuffs. It is only a habit of mind which we have acquired through familiarity with houses and machines which leads us to think that way.

But admitting that one might form some general concept of a whole before discerning parts, is it nevertheless not true that a whole is nothing more than the sum of its parts plus whatever interrelations may exist between its parts? This is indeed true with regard to some wholes; namely, the artificial wholes

BOSTON UNIVERSITY
COLLEGE OF LIBERAL ARTS
LIBRARY

which men construct; but it is not true of organic wholes such as we commonly find in nature. Certainly it is not true of organisms. Let us examine this assertion from the standpoint of a part.

A thing may become a part in one or the other of two ways: (a) It may begin as a discrete and independent unit and then by integration with other units secondarily find itself a part of a whole. Thus the brick becomes a part of a house. Thus also a balance-wheel becomes a part of a watch. Houses and watches as thus fabricated are merely the sums of inter-related parts. Their wholeness, or had we not better say, their togetherness, is the result of a "creative synthesis" which has taken place. Their special properties depend upon the special relations between their constituent parts. (b) In organic wholes, on the other hand, the whole exists first, and the part arises by differentiation within the pre-existing whole. Homogeneity precedes heterogeneity. At first the parts are indistinguishable from one another except, perhaps, by future reference. Thus a "part" of a lump of clay may be described as the prospective handle of a vase, or a part of an amphibian egg may be termed "presumptive neural plate"; but the part is not as yet handle, nor neural plate; nor is it entirely certain that it will become such.

Organic wholes, then, are not primarily composed of parts, or even of inter-related parts. They are not the result of an integration or of a "creative synthesis." Quite to the contrary, they precede their "parts" in time, and remain superior to them in space.

It is likely that the reader is not convinced. Perhaps he is a morphologist and is engaged in dissecting organisms and studying their structures, dead or alive. To him the organism is a definite pattern in space; or indeed a succession of such patterns, if he be an embryologist. But the morphologist's organism is, of course, not the whole organism. It is only that aspect of the organism which he has chosen to abstract and study. Perhaps the reader is a physiologist, and concerns himself with the functioning of organs or the rôles of forces. He, no doubt, has become much interested in the interrelationships of processes, and has noted the remarkable self-regulating devices within the functioning system. But his organism, like the organism of the morphologist is an abstraction from the whole.

To study the organism as an organic whole, one must be interested not merely in the organism which is and does; but he must know also what under other conditions and in other relationships this same mass of living matter will be and do. He will want to know how and why the organism came to be what it is and to do what it does. Indeed, he will go further and will seek to comprehend, if possible, the nature of the organic wholeness in itself; that is, the wholeness which precedes the being and the doing, and which gives to parts their significance.

Let us illustrate this by reference to a very primitive animal, the fresh-water polyp *Hydra*. A piece of the body stalk of this animal is morphologically only a piece of the body stalk. As such it may be killed, sectioned, reconstructed, and described. Physiologically it is an organization of more or less specialized cells carrying on the numerous functions of living. But isolate this piece of the stalk (the following is true of the central portions of the stalk), and immediately these same cells commence to reorganize themselves; and in a short time a whole new polyp has been formed (Trembley, 1774). It is therefore true that what a part of a polyp is and does is a function of its

position in a whole; and the whole must be understood first, if the structure and functioning of the part is to be comprehended.

In the discussions which follow, the living matter will be treated as though it were a single system; which, of course, it is. For our present purposes it will not be necessary, except incidentally to consider the division of protoplasm into nucleus and cytoplasm; nor its subdivision into cells (Whitman, 1893; Sharp, 1934). It will even be unnecessary to consider the individual activity of the various neoblastic and restitution cells by which the molding and regulations of organisms is accomplished (Stolte, 1936). These cells, important as they are, act within and are subordinate to the pattern of the organism as a whole. Furthermore, problems of heredity and environment, such as the action of genes and of physical factors upon the course of development, need not detain us here. All of these various elements which contribute to development and regeneration may be looked upon as problems of the second order; second, that is, to the problem of the development of the organism considered as one system.

II

At least two concepts of wholeness are possible. According to one, the part is what it is, and does what it does, by reason of its present relationship to a labile and self-regulating whole. The organism, according to this view, is a system tending toward equilibrium, of the type which has recently been termed a "configuration" or "gestalt" (Köhler, 1927). According to the second view, the part is what it is because of its relation in a system which has had a common origin and is evolving together (Schaxel, 1922). The organism is a system undergoing a history. According to the first view time means little to the organism; and development may be backward as well as forward. According to the second view, time is of the very essence of life (cf. Bergson, 1913, p. 16). We shall consider the first of these two concepts in the present section.

The configurational or gestalt viewpoint gives us a clear picture of reproduction. Every organism is at first a part of a pre-existing organism. It is a "chip off the old block." By development the part regulates itself into a whole (cf. von Baer, 1828). The part may be a portion of a cell, as when a protozoön divides to form two protozoa; or it may be a single cell, as when an egg develops into a many-celled being; or it may be a group of cells, as in asexual reproduction by budding or by fission. In fact, when looked at thus, reproduction and regeneration are seen to be of the same stuff, for in both a part remodels itself into a new whole.

How shall one visualize a gestalt or organismic pattern of wholeness? Those who have made the attempt have generally conceived of an active "field" (physiological gradients, Child, 1915b, 1928; embryonic field, Gurwitsch, Rudy, 1931, Weiss, 1926; gradient-field, Huxley and DeBeer, 1934, Huxley, 1935a) in which the forces; for example, the concentrations, potentials, rates of activity, tensions, and such like; are oriented and gradated with respect to the pattern as a whole. Each point within the field thus possesses the two vector characters of direction and dimensions; and it derives these characters from its position within the field. The field may be a simple linear field, as when a hydranth regenerates at the end of a piece of hydroid stalk (Driesch, 1897; cf. Gilchrist, 1937). It may be a two-dimensional field, as when a chick blastoderm (Waddington, 1932) or the neural plate of an amphibian embryo (Kingsbury,

1922) becomes structurized. Or it may be a three-dimensional field, as in the differentiation of a limb bud (Harrison, 1918, 1921; Milojewić, 1924). But in any case it is the location within the field which gives to parts their significance, and which makes it possible to say of a given cell or area that it is prospectively this thing or that.

Fields obey certain "field laws" which have to do with wholeness and with unity. (They obey these laws provided, of course, that the material which composes the field remains plastic and labile.) By *wholeness* is meant the tendency of the field to assume and maintain orderly and complete patterns, in which the parts are arranged in normal sequences and characteristic relationships one to another. By *unity* or oneness is intended the proclivity of the field to possess a single center of dominance or control, to which adjacent areas are subordinated, and in spatial relation to which field forces are organized (i.e. oriented and gradated). It is not easy to separate unity and wholeness; yet to a degree they are distinct. Thus a crystal may be said to possess wholeness but not unity, since it lacks a center of control, and since it would be possible to cut a crystal into parts, each part a whole. A crystal is thus an orderly aggregate rather than an individual. On the other hand an incomplete object, for example, a half embryo or a defective limb, may have a degree of unity (single center of control) and yet not be a whole.

The "field laws" which primarily concern wholeness may be stated as follows (cf. Weiss, 1926):

(a) When material is taken from a field, the remainder reorganizes itself into a new whole field. In fact, when a field is subdivided into two or more parts, each part immediately reconstitutes itself a whole field of smaller size. Thus a piece of a flatworm, or an isolated blastomere of a sea-urchin egg (Driesch, 1900a) or half of the limb area of an amphibian embryo (Harrison, 1918) will develop as a whole. A very small piece of an unfertilized sea urchin egg may, after fertilization, develop a whole embryo, balanced in all its structures, yet of small size (Tennant, Taylor, and Whitaker, 1929).

(b) When two fields are brought together harmoniously; that is, with their axes oriented and gradated parallel to each other, the two fields fuse into one, and a single whole field of double size results. Thus two sea urchin eggs fused together may produce one giant embryo (Driesch, 1900b).

(c) When two fields are brought together disharmoniously, that is with their forces not parallel, adjustment between the two fields takes place, and some sort of reduplication results (Bierens de Haan, 1913). Of this nature are the numerous types of double and multiple monstrosities which are sometimes found in nature.

(d) When a small region of one field is implanted into another location (or in another orientation) in another field, either one or the other of two things happens: If the implant is sufficiently plastic and labile, it will become an integral part of the larger field, and will develop according to its new location in the whole (Spemann, 1918; Mangold, 1923). If, however, it has attained to some degree of stability, it will distort the field, at least locally, and some sort of an abnormality will result.

(e) When a field is subjected to an environmental force acting in one direction, it sometimes happens that the orientation and dimensions of the field are altered, or even reversed altogether. For example, the orientation and hydranth size of a regenerating piece of hydroid stem is much influenced by any contacts of the piece with the bottom (Child, 1915b, 1927). Also a temperature differential imposed upon a developing amphibian egg is able to profoundly affect the symmetry and balance of the embryo which results (Gilchrist, 1928, 1929). By such distortions, however, the wholeness of the field is not destroyed.

A second series of "field laws" have to do primarily with unity. (We here follow rather closely the account of Child, 1929, pp. 22–25; see also Huxley and DeBeer, 1934.)

(a) Some region of the field is commonly a "center of intensity" (Spemann), apex, or high point, in spatial relation to which the entire field is organized. This is the principle of "physiological dominance." The orientations and gradations which are thus determined constitute one aspect of what is termed "polarity."

(b) The center of the field becomes during develop-

ment some particular part of the organism. For example, the high end of the gradient of an egg or a fragment of a hydroid becomes by development or regeneration, the lips of the mouth. This is a self-differentiation, since it may take place quite independently of other regions. For example, a very small piece of a hydroid, if it regenerates at all, will form oral lips even when other parts are lacking (Child, 1907).

(c) Other regions of the field develop in spatial relation to the center of the field. This is known as "physiological subordination." The center becomes one thing; the subjacent areas become other things according to their relative positions in the center-controlled field. It is thus that the oral, tentacular, and sub-tentacular zones of the hydranth are determined.

(d) One of the influences exerted by a dominant center upon subjacent levels is that of inhibition (Rand, 1924). For instance, if two apices should begin to develop not far from each other, it commonly happens that the more active or favored of the two inhibits the development of the other. It is itself not inhibited.

(e) By sufficient local stimulation it is sometimes possible to liberate a subordinate region from the control of a dominant center and permit it to be free. This is "physiological isolation." The region then becomes the center of a field of its own, a new development occurs, and a new individual is produced. For example, a wounded area on the side of a hydroid is sometimes able (presumably as a result of the increased metabolism of healing) to become the dominant center of a new organism (Child, 1928).

(f) The different regions of a field are differentially affected by conditions of the environment. Thus the dominant area of a field is commonly the first to succumb to lethal concentrations of a toxic chemical ("differential susceptibility"), and the first to recover from the effects of sub-lethal concentrations of the same reagent ("differential acclimatization") (Child, 1927, 1928).

Too much emphasis, however, should not be placed upon the one-way (dominance-subordination) relations of regions within the gradient-field. Hörstadius (1935) in particular has showed that normal development in the sea urchin requires a balance between the "ectodermalizing" gradient which centers at the animal pole, and the "entodermalizing" gradient which has its center at the vegetative pole of the blastula. There is reason to think of the field as a self-adjusting configuration which adapts itself to the size and shape of the material, the distribution of such differentiated stuffs (see later) as may be present, and also to the forces of the environment.

An important question concerning a gestalt or field pattern is its relation to the second law of thermodynamics. Does the field represent a static equilibrium or configuration of rest, toward which the living system tends, and in which its forces are balanced (Köhler, 1927)? If so, then the field is a state of maximum entropy, like the fluid of a suspended drop. Or does the field represent a "dynamic equilibrium," comparable to that which gives form to a water-spout, or to a candle flame (cf. Roux, 1905, pp. 105ff). If this latter is the case, then the forces of the field are at least in part kinetic; entropy is not at a maximum, and work is being done. To one observing the organism solely as a form in space, it will seem as though the field were indeed a static equilibrium; but to anyone who will come close enough to the organism to see its life processes in action, the field will appear, rather, as dynamic (T. H. Huxley, 1879, pp. 84–85).

Certain corollaries follow, if we may accept this second viewpoint. Should experiment finally confirm these corollaries, the fact would go far to place upon a physiological basis, the science of organismic form or pattern.

(1) If the dynamic field is to persist, energy must be continuously supplied. Let the wind cease to blow, and the water-spout will collapse. Let combustion fail, and the candle flame will go out. Let oxidative metabolism (or other source of energy) cease, and the field within the organism will be wiped away. It is thus, so we may believe, that many of the marine invertebrates when exposed to cold or to lack of oxygen, lose their patterns of differentiation and melt down into formless masses (Driesch, 1902;

Huxley, 1926). Thus also an egg or embryo, when similarly treated may lose the unitary field which would have produced a single embryo, and on return to more favorable conditions may regenerate two or more, often disordered fields (Stockard, 1921). In some such manner twins are produced.

(2) A second corollary is that the energy required at any point to sustain the gradient-field at that point will depend upon the steepness of the physical and chemical gradients rather than upon the absolute value of concentrations or potentials. In mathematical terms, the energy required to maintain the field at a position, S, will depend, not upon C (e.g. an absolute concentration) but upon dC/dS. This is true, of course, provided that the field remains labile.

(3) A third corollary is that two fields will require more energy to sustain them than one field which is equal to the sum of the two fields in size. At least this will be true if the larger and the smaller fields are equally able to produce and to sustain like differentiations of structure. This follows from the fact that in the smaller fields the gradations will be steeper, and will therefore require more energy to preserve them. For example, it is said to take more energy for two isolated blastomeres of the sea urchin egg to produce two whole embryos of half size, than it takes for these same two blastomeres when united to produce one embryo of full size. (Tyler, 1933, cf. 1935. Tyler gives another explanation.) Again, when pieces of the lower organisms are cut smaller and smaller, the regenerations which result are less and less complete, and require more and more time. Presumably in the smallest pieces the energy available is inadequate to support a field of sufficient steepness to produce organic differentiation at all.

What may be the physical nature of a field? Some speak in terms of molecular orientation and crystal structure (Loeb; Driesch, 1908; Przibram, 1929); but if so, one must think of the orientations as at least for a time labile and subject to the forces of the field as a whole. Some speak of tensions (Morgan, 1901; Weiss, 1933), or of forces of attraction and repulsion. Others find evidence of gradations in structural and functional properties of many sorts: concentrations, granule size, electrical potentials (Burr and Northrop, 1935), rates of respiration (Child), degrees of irritability. Perhaps no one of these qualities *per se* is the nature of the field, but the field is all of them taken together. Perhaps we can never hope to find one thing which is the physical basis of organic wholeness. This possibility, however, should not discourage anyone from seeking to discover the relations of the field factors to each other and to the processes of development.

It is of interest to enquire as to the extent to which the dynamic field forces—if such they be—persist into the adult life of the organism; or does the field subside as an active, functional field and require to be reawakened whenever regeneration takes place? Is the visible organism comparable to the bed of an actively flowing river (Child, 1915a, p. 27f), which is being continuously formed and molded by the forces of the moving water? Or is it the bed of a "dry river" which once flowed but is flowing no longer? Are the gradients which reveal themselves in rates of development and growth, to be taken as the direct evidence of an active morphogenetic field; or are they the relics of a field which once was present but is no more (cf. Huxley, 1935a)?

In the lower organisms it is fairly apparent that the active field persists through life, although possibly it is of less potency in the adult than in the embryo. Thus a hydra retains considerable powers of self-regulation. If a tentacle be grafted into the shaft of one of these animals, it will do one of several things (according to location): It may fall away. It may be resorbed. It may migrate into a proper position within the circle of tentacles. Or it may establish around itself a field of its own and cause an outgrowth or bud to develop (Rand, 1900; cf. Steinmann, 1927).

Similar regulatory processes occur in the embryos of higher forms. Thus if the limb bud of a salamander embryo be revolved into a new orientation, it will

commonly rotate back to its proper position (Nicholas, 1924). There is considerable evidence, however, that in the adults of higher animals, the fields subside to a very low ebb or disappear altogether. The various gradients and orientations which persist are probably evidences of a field that was and is no more. Thus the integumentary pattern which is revealed in the size, shape, and rates of growth of regenerating feathers of a bird, would seem to disclose only a "residual field" (Fraps and Juhn, 1936). The active field forces which gave rise to the pattern are gone.

This likelihood that the active fields of higher forms may deposit, as it were, various material and physiological gradients and then cease to be, brings us to an entirely different conception of organic wholeness from the one which we have just considered.

III

The second general concept of organic wholeness to which we call attention is the historic. According to this view the parts are unified in development, and present a definite pattern or configuration because they are derived from a common source (the egg) and have endured a common experience. Of this nature is the wholeness of the sky-rocket, which bursts into a symmetric pattern and fades away. Such also is the wholeness of a flower, which unfolds its characteristic pattern and dies. Any injury to the bud must result in imperfection in the flower.

The historic concept of wholeness gives us a clear picture of the life cycle. The germ cell or bud blossoms, as it were, into an embryo, and then progresses onward step by step through the stages of youth, maturity, and old age, to end finally in death or reduction. Viewed as history the processes of development are thus straight-forward and irreversible. If a protozoon be injured to any except a very minor degree, it does not directly heal its wound, but instead it wipes away its entire previous organization and begins a new development from the start (Taylor, 1935). (The wiping away or reduction is something quite different from a mere backtracking of the previous course of development.) If a defect be inflicted upon an egg or embryo, either one or the other of two things happens: If the defect occurs before development has structurized the part removed, then development continues normally. No reversal of history takes place, because no history has been made. The apparent regulation is not true regulation at all, for no differentiation is present to be regulated. If, however, the defect be inflicted after structurization has begun, the result is a more or less defective organism. (This is not to deny the possibility later of considerable "functional regulation" of the size and even of the positions of organs; nor of the remarkable processes in which specialized "embryonic" cells tear down and rebuild structure.) If a tadpole be fed thyroid it will transform itself into a frog, but the reverse transformation has never been observed. (There are characters, however, which remain plastic; for example, the secondary sexual characters in some of the higher organisms may even be reversed by changing the internal secretions of the gonads. Witschi, 1934.) Finally, an organism which grows old can apparently never become young again, except in so far as old differentiated cells may be removed and young embryonic cells take their place. It is thus possible to conclude, after making due allowance for numerous apparent exceptions, that life histories are predominantly straight-forward and irreversible "from the cradle to the grave."

The historic viewpoint raises the question as to what extent the straightforward, irreversible processes of ontogeny are predetermined? Or are they free? Is each individual organism actually something new? Or is it only the unfolding of something which was already present?

From ancient times to the present day biologists have generally rebelled against concepts of freedom. History there is, so they will agree, but it is not true history, creative and full of novelty. Organisms develop according to type. It has seemed necessary, therefore, on *a posteriori* grounds, to find the consequent in the antecedent; the organism in the egg. Let us review some of the ways in which a doctrine of freedom and novelty in development has been avoided.

(1) The early microscopists (of the 17th and early 18th centuries) not only denied novelty in development, but they denied development. With the aid of their imaginations they thought that they could actually see the organism preformed in miniature within the germ cell and needing but to grow. Some said that they saw it in the egg, some that it was present in the sperm. This is the doctrine of crude preformation.

(2) The pioneer embryologists of the late 18th and early 19th centuries, with better lenses and less vivid imaginations, saw that the organism is not preformed, but that it is at first simple, and that during development its structures come into existence *de novo*, one by one. This view is radical epigenesis. To escape the doctrine of novelty in development, however, these same embryologists postulated a vital force or soul. This was supposed to superintend development and render the result orderly. Thus they placed the problem of organic wholeness outside the bounds of science altogether.

(3) The last half of the 19th century brought attempts to substitute materialistic explanations for the vitalistic assumptions of a soul. The organism, so it was now thought, although not crudely preformed in the egg, was at least prerepresented in some fashion, part for part. Thus there appeared a series of hypotheses based on coteries of representative stuffs or particles.

Darwin (1875) proposed his hypothesis of cell-determining gemmules. Roux (1883a) had a doctrine of region-forming qualities. DeVries (1889) advanced his cytoplasm-forming pangenes; and Weismann (1893) his complex architecture of the germplasm, consisting of idants, ids, determinants, and biophores. The rediscovery of mendelian inheritance (about 1900) brought to the front the hypothesis of unit-character-determining genes. Related to these doctrines of representative particles were those of cytoplasmic inheritance. His (1874) proposed his pre-localized organ-forming germ regions; Nägeli (1884) his highly organized, net-like idioplasm. There were many other views of pro-morphology, of egg organization (Whitman, 1878), and of the egg as an "embryo-in-the-rough" (Loeb, 1916). The doctrine of organ-forming stuffs was developed (Conklin, 1905; Rabl, 1906); and special importance was assigned to certain regular aspects of the cleavage process (Conklin, 1898).

Each of these hypotheses, which we have just named over so rapidly, denied freedom to the organism, and any possibility of novelty to the normal processes of development. Each hypothesis was in fact a method of finding the organism in the egg. (This is, perhaps, not quite true of the doctrine of organ-forming stuffs, which lightly invokes processes of stratification, localization, or segregation of the stuffs, and so begs the question of the origin of organic wholeness.)

(4) Different in principle from the foregoing hypotheses are those which consider the organism to be the product of the interaction of numerous discrete entities which are *all alike*.

Of this type was Spencer's (1866) hypothesis of physiological molecules; Driesch's (1908) concept of a polarized intimate structure; and Przibram's (1929) space lattice or crystal theory. In each of these each smallest unit of the organism is in effect a microcosm which bears within itself the whole character of the species. These theories come very close to being gestalt views, and should perhaps have been considered under that heading, for they consider the developed organism as a sort of equilibrium in which the forces of the constituent units are satisfied. Moreover the view ascribes a controlling function to the whole; for, as Spencer says, the units, although all alike in structure, yet vary widely in their functioning, acting "at all times in such a manner as the whole demands." Yet the microcosmic theories, if they do not entirely rule out novelty, at least hold it to a minimum, for the organism is pre-represented in each and every one of the numerous units which compose it.

(5) The modern theory of the gene, although derived directly from the mendelian doctrine of representative particles (factors representing unit characters), has tended more and more to become a microcosmic hypothesis in which each nucleus possesses within itself the entire character of the species. Manifoldness exists from the beginning, but not in the form of numerous discrete units, as Mendel supposed; but rather as an organization of entities known as genes. At the times of cell divisions these are seen to be arranged in definite order in the chromosomes, which in turn compose the nucleus. Each gene, moreover, has not only its effect as a unit, but it has also a position effect, due to its relation to the other genes (Dobzhansky, 1936). In the opinion of most geneticists, however, there is but little opportunity during development for freedom of action, or for novelty. The organism, so to speak, already exists in microcosm within each nucleus. (This view was well stated by Wilson, 1905, p. 292.)

(6) From the geneticists we pass to the experimental embryologists. We may designate their usual outlook as the "modern theory of the potency." Quite unconsciously, for the most part, embryologists have supplied the organism in the egg, and thereby lost sight of novelty in development—by the mere use of a word.

Ever since Driesch in his analytical theory of development raised the question as to how the "prospective potency" of a part (that is, all the possible fates which a part might have) becomes restricted during development to its "prospective value" (that is, to the actual fate which the part does have), the usual formulation of the problem of development has been somewhat as follows:

> At the beginning of development each portion of the egg possesses the *potencies* of becoming any structure of the embryo. During the course of development a segregation (Lillie, 1927, 1929) and restriction of *potencies* occurs, with the result that each portion retains the *potency* of becoming but one thing. It then proceeds to become that thing.

Now, the first difficulty with this formulation is that it uses the word *potency* in two senses, and so buries the essential problem of development completely out of sight. This point is so germane to our subject that it will be necessary to discuss it at some length.

> Originally the related word *potentiality* meant "power" (puissance; Vermögen), but by a weakening of sense it has come to mean also "possibility, not actuality" (Möglichkeit). Similarly the word *potency* was originally and rightly used only in the sense of power. Webster's *New International Dictionary* defines it variously as "inherent strength or power"; "specific efficacy or capacity"; "ability to effect a certain result"; "capability for developing in accordance with its nature". Unfortunately, at least since Driesch's earlier writings, the word *potency* has been used by embryologists in the weakened sense of "possibility". Thus we read of the *potencies* of a cell for example. But the modern embryologist is quite apt to go further and to reify the concept; that is, he uses the word *potency* as if it stood for a thing (cf. Woodger, 1929).

With these definitions in mind, let us reformulate our statement of the problem

of development, substituting the words *possibility* and *power* as the sense may require. (Since power is also sometimes used in a weakened sense, let it be emphasized that it here always refers to inherent, specific efficacy or "self-differentiating" capacity.)

At the beginning of development each portion of the egg possesses the *possibility* of becoming any structure of the embryo. During the course of development processes occur by which each portion loses the *possibility* of becoming anything, and acquires the *power* of becoming one thing. It then proceeds to become that thing.

Stated thus it appears that development is a dual process, involving on the one hand loss, on the other hand acquisition (cf. Vogt, 1927; Dürken, 1928; Raven, 1935). But let us examine further this idea of loss. What are lost are possibilities. (We shall allow for the moment the use of the plural.) Now possibilities are not real things. They are only possible courses of development which a given system as a whole may pursue. Moreover, we can know possibilities only by thinking backwards. We perform numerous experiments to find out, so far as we can, the many different things which a region can do and become. Then we turn our thoughts around and say that the region possesses the possibilities of becoming all of these things. In doing so we throw away the various inducing and interacting conditions which enabled the region to realize this, that, and the other fate. Nevertheless, forgetting what we have thrown away, we say that the region possesses the *potencies* of becoming these many things. No doubt this use of language has some descriptive value; but as a way of explaining the processes of development, it is, to say the least, misleading.

It would be equally misleading, however, to suppose that a sharp line can be drawn between possibilities and powers, or that a region becomes a sharply defined organ rudiment with a definite power suddenly. Powers come into existence gradually, and, moreover, they are at first diffuse in their distribution. It is possible, therefore, for a region to be in a state intermediate between possibility and power. The epidermis of the head of a young amphibian embryo, for example, possesses the "competence" (Waddington, 1932) of forming a lens, but (with some exceptions) it does not actually form a lens unless it comes into contact with an optic vesicle (future retina of the eye). "Competence" here refers to a sort of imperfectly developed power or latent potency which requires some further stimulus to "activate" it and render it effective. We shall have occasion to return to this topic in the next section.

By a shift in the meaning of the word *potency*, then, and by reifying the concept of potencies, many embryologists have quite lost sight of the fact that *powers must originate during development*, whether suddenly or gradually; and thus they have avoided the problems of freedom and novelty altogether.

(7) Let us now leave these several ways in which the concept of freedom has been avoided, and let us frankly face the possibility that development is true history; that each individual organism is not pre-represented in any sense within the egg; but that it is actually created afresh, step by step, as development progresses. We may then reformulate the problem of development as follows:

At the beginning of development no portion of the egg possesses in itself the *power* (specific efficacy) of becoming any definite structure of the embryo. During the course of development processes occur by which the various portions acquire *de novo* definite *powers* to do and to become definite things. These things they then proceed to do and to become.

The processes referred to have been variously termed determinations, chemodifferentiations (Huxley, 1924), and invisible differentiations. Years ago Wilson (1894) called them physiological specializations.

He regarded "the specific structure of the cell to have arisen, not through the segregation and isolation within its boundaries of special idioplasts or germ substances, that have been sifted out by qualitative division, but through a physiological specialization (as de Vries and Hertwig insist) that may have taken place before, during, or after cell-division, according to circumstances."

The essential feature which we would emphasize here is that these determinations, invisible differentiations, or specializations, are novel events, which are free and in part fortuitous and unpredictable (although not, of course, indeterminate). Let us illustrate this matter by reference to the history of the amphibian egg.

Presumably there is a time in the very early (ovarian) history of the egg when the position of the animal pole has not been finally decided. However this may be, it is certainly true that while the egg is yet in the ovary the dorsal side is still uncertain (Roux, 1883 b; Fankhauser, 1930). At an early state, therefore, it cannot be said of any definite region of the egg that it is prospectively this or that structure of the embryo. Then processes of structurization occur. Hypothetically we may picture the egg-to-be as developing an intrinsic tendency to become polarized; that is, to form an eccentrically situated pole-plasm. Some force of the environment outside of the egg no doubt decides on which side of the egg the pole-plasm shall form. Next (in amphibian development this occurs soon after fertilization) a process takes place by which there develops on one meridian of the polarized egg a specialized dorsal-plasm. Thus the egg becomes bilaterally symmetrical. From the standpoint of the organism itself, both these processes are novel events which could not have been predicted, and in which something entirely new has been created.

With the appearance of these two "axes" (or rather specialized areas), each region of the egg may be thought of as acquiring a definite prospective value according to its location. But prospective value is not a real property which a part possesses. It is only the embryologist's expectation of the future fate of the part, an expectation which he has formed by thinking backwards along one particular course of development; namely, along that particular course which he has chosen to designate as "normal" development. A given region may thus be called "prospective mesoderm"; but it is still quite a fortuitous circumstance whether it becomes mesoderm. If perchance when the time of its invisible differentiation arrives, the region in question finds itself still on the external surface of the embryo (due, shall we say to some interference with the usual process of its gastrulation), the region will not acquire the power to become mesoderm, but instead may become epidermis (Töndury, 1936). Similarly the outer ectoderm of the gastrula either develops the power to become neural plate, or it does not develop this power. Whether it does or does not depends entirely upon whether it becomes underlain by some so-called inducing agent, normally by the archenteric roof (Marx, 1925; Holtfreter, 1934). It is of course true that nature with the help of natural selection has developed stabilizing mechanisms, for example, investing membranes, by which to preserve a fairly uniform environment outside and inside the egg or embryo. As a result development commonly slips along quite smoothly and pretty much according to a pattern.

Moreover, nature has apparently provided the developing system with various mutual interactions of a regulatory nature, so that, as Spemann has put it, the development of an orderly embryo is "doubly or even multiply assured" (Spemann and Geinitz, 1927). Yet in spite of these precautions, the natural occurrence of monstrosities is all too common; and the artificial production of abnormalities by the experimenting embryologist is almost no trick at all. Thus, we conclude, the development of an organism is not something that was prescribed in advance. On the contrary, it is in essence a program of creation which is free and full of novelty. (Freedom, of course, signifies lack of constraint, not absence of determinism.)

To the developing organism, then, every step is a new adventure over ground which it has never been over before, and over which it never will return. Every problem is for it a fresh problem, which it must meet in the spirit, as it were, of a pioneer. And if, as usually happens, it meets its problems in essentially the same fashion in which countless similar organisms have met their problems before, it is because it is made of the same stuff as they. No ready made charts are at hand to guide the organism on its way; no supervising genii, either æthereal or corporeal are present to make decisions for it. It is free; and it has no laws to guide it but the laws of the nature of its own being and of the place in which it dwells.

IV

We have now two concepts of organic wholeness before us: On the one hand we have the view that the organism is a configuration or gestalt of a particular sort; namely, a labile system tending toward a "dynamic equilibrium," and comparable, for example, to a candle flame. On the other hand, we have the view that it is of the nature of a true history, straight-forward and creative, to be compared to a sky-rocket which bursts into an expanding pattern and fades away. On the face of it these two viewpoints are incompatible and contrary, the one to the other. How can development be at the same time centripetal, the realization of a pattern of wholeness which was to come; and centrifugal, the achievement of a germ cell past? According to the first view time means little; and development may be backward (as in rejuvenation, so-called) as well as forward. According to the second view time means much; development gets somewhere.

Evolutionists and students of heredity have generally adopted the historic viewpoint. To them the organism is as a flower, borne on its ancestral tree, which blossoms and fades; but the stem, that is the germplasm, continues on immortal but not unchanging. Embryologists and students of the life cycle have likewise tended to stress the historic alternative; for they have observed the straightforward processes of invisible differentiation by which the egg becomes progressively structurized into a mosaic of parts having unlike capacities in development. They also have come to think of the organism much as a flower, which injured in the bud must ever show its injury. Students of regeneration and of the regulatory powers of the organism, on the other hand, have been impressed with the gestalt viewpoint; for they have seen the organism adjusting and adapting itself, and have observed its ability to attain the same specific end by more than one route (Berrill, 1935). With these phenomena in mind they have rejected the analogies of the tree and flower, and have pictured the organism more as plastic clay, any part of which is able, at least in principle, to live and reproduce its

kind. They have found continuity, not in a separate and immortal germplasm, but rather in the living system itself, one primary property of which is its power to assume and to maintain a specific and unitary organization or wholeness. How shall we resolve this basic and fundamental dilemma which lies at the heart of the biologist's doctrine of the organism? Any adequate answer must of necessity be based on well-planned experimentation and upon careful analysis. The argument which follows has been adapted from a recent article by the author (Gilchrist, 1937) entitled: "The scyphozoan polyp *Corymorpha palma* as gestalt and as history." (See also my analysis of budding and locomotion in the scyphistoma of *Aurelia*, Gilchrist, 1937.) However, as here presented, the argument refers to amphibian development, rather than to regeneration.

As a first assay at analysis, let us suppose that a human workman was to undertake to form an embryo from, let us say, a ball of clay. He would no doubt begin by measuring out the portions to be assigned to each part of the embryo. After this was done, he would commence to fold and mold. But before he could measure he would have to make some preliminary observations. First he would have to comprehend the material as a whole, for only then would he be in a position to choose where to begin, in what direction to measure, and the scale. He would need to choose the scale so that the embryo when finished would be proportional to the material available.

Does nature go about her work in this same methodic manner when she hews an embryo from an egg, or from a part of an egg, or perchance from two eggs fused together? Does she progress by these three steps when she structurizes a new limb from the blastema of an amputated appendage of a salamander, or a new flatworm from a fragment of an old flatworm? A. Does she first comprehend the material as a whole, choose the place to begin, the direction in which to progress, and the scale? B. Does she then measure out and assign to each part the rôle it is to play? C. Lastly, does she begin the process of actually molding the material into its final form and structure? Considerable evidence is at hand which indicates that nature does indeed proceed by these three steps.

Before we outline the evidence, however, it will be well to restate our analysis in as nearly as possible physical terms: The structurization of a region (in the first instance of the whole embryo or regenerate) may be considered to pass through three phases: A, a *phase of organization* (cf. Weiss, 1926) in which a simple, quantitative pattern or gradient-field is established within the region; B, a *phase of invisible differentiation*, in which qualitative differences arise within the region, and the parts acquire definite and diverse powers (specific efficacies) for development; and C, a *phase of visible differentiation*, in which the invisible powers which have thus arisen express themselves in different developmental activities; such as thickenings, thinnings, inpocketings, outpocketings, cell migrations, and tissue differentiations.

A. By organization a gradient-field originates which gives order and unity to the region undergoing structurization. In the case of an amphibian egg, the animal pole has usually been assumed to be the high end of the gradient (Child, 1924), the center of the field. However this may be at first, there is some evidence that in time the material which borders the denser yolk (corresponding to the margin of a chick blastoderm) becomes the "center" which at least stabilizes

the primary or polar gradient-field (Penners and Schleip, 1928). Next, one side of the marginal material (marginal presumptive entoderm) becomes the "center of organization" (Spemann, 1918) which determines the dorsal side of the embryo. If two such centers of organization should develop, as sometimes happens, or if two such centers should be experimentally produced (Spemann, 1919), then a double field will be organized, and a double embryo will result. The gradient-field thus establishes the polarity, bilaterality, and laterality of the embryo. The steepness of gradation within the field presumably decides the dimensions upon which the ensuing differentiations shall proceed, and hence the relative sizes of the organ rudiments. Smaller pieces produce smaller embryos. The gradient-field is at first highly labile and readily adapts itself to the form of the piece and the forces of the environment. For instance, during the first few minutes following fertilization, the dorsal side of the amphibian egg is subject to modification (Fankhauser, 1930). As soon, however, as any differentiation has begun, the specialized regions tend to stabilize and anchor the field against forces which might disturb it. Thus in the blastula the position of the early dorsal lip is established, although the locations of the remaining organ areas of the egg are still labile (cf. Gilchrist, 1935). Most important of all, the gradient-field has always the aspect of wholeness, and obeys the laws of fields, as already listed.

In short, the gradient-field is simple, quantitative, and labile. It gives unity, direction, and dimensions to the differentiations which follow. It has always the aspect of wholeness; and when it has become established, the parts within the field have definite prospective fates (provided, of course, that the further course of development be "normal"). The field thus gives significance to location, and special meaning to the concept of the "organism as a whole." If it were not for the process of organization, the differentiations which follow could not possibly give rise to integrated structure, but must produce a hodge-podge or heap.

B. By invisible differentiation qualitative diversity originates in spatial relation to the gradient-field, and imparts to the several parts of the field the powers to do and to become definite things in development. We may picture the process as a wave of chemical change, which, beginning at the center of the gradient-field, sweeps over the field, changing in its specific nature as it goes. First, we may suppose, a material is elaborated in the initial dorsal lip area which imparts to it the power to form the mouth region and the roof of the pharynx, and to induce in overlying ectoderm the capacity to form sensory and other ectodermal structures of the head. Lateral to this a zone of material is laid down which brings with it the power to form entodermal gill pouches, and to induce in adjacent mesoderm and ectoderm their corresponding visceral structures. Above the initial dorsal lip is an area which acquires, presumably by chemo-differentiation, the efficacy of becoming prechorda, notochord, and somites, and of inducing neural structures in any ectoderm with which it may later come into contact (Spemann and Mangold, 1924; Bautzmann, 1926). Thus, beginning at the initial dorsal lip and progressing outwards, the various developmental powers of the entoderm and chorda-mesoderm are established.

Even in this very brief account we have begged several vital questions. For example, it is likely that the invisible differentiations which proceed from the region of the dorsal lip of the early gastrula, impart merely the *power to move* (Gestaltungsbewegung) in

definite fashions during gastrulation (cf. Vogt, 1924). The powers or specific efficacies to differentiate into the various structures of the neurula, probably do not appear, or at least do not become fixed, until after the materials in question have passed beneath the lips of the blastopore (Detwiler, 1933).)

In principle, then, invisible differentiations are qualitative processes in which limited areas of the developing region acquire special powers of development which the same areas did not before possess. In general, the potential rudiments or "preprimordia" which thus arise are larger and more diffuse than the definitive organ rudiments which later become visible (Harrison, 1921b; Huxley and DeBeer, 1934, p. 237). They may even overlap one another.

C. In due time the potential organ rudiments undergo visible differentiation; that is, they express themselves in diverse developmental activities, and the embryo begins to take form. The central areas of the diffuse potential rudiments become the sharply delimited rudiments or "primordia" of the descriptive embryologist.

Now, the first processes of structurization; namely those by which the egg (or regenerating fragment) as a whole becomes subdivided ("autonomized," Weiss, 1926; cf. "elementary processes," Driesch, 1908) into a group of secondary regions, are followed by further structurizations within each sub-area. In general, it would appear that these secondary structurizations begin before the visible differentiations of the first structurizations are complete. However, in a formal way, we may still say that each structurization, primary, secondary, or of higher order, passes through the same three phases of organization, invisible differentiation, and visible differentiation.

With the appearance of diversity within the developing system, however, a new type of developmental activity begins. The differentiated regions and sub-regions act and react with one another by processes known as *embryonic induction* (see Weiss, 1935), with the result that the embryo becomes increasingly manifold—yet orderly. These various inductions, however, (for example, the well known induction by which chorda-mesoderm induces ectoderm in contact with it to become nervous tissue) are to be carefully distinguished from localized invisible differentiations within a gradient-field. The first (induction) involves direct action, and is presumably of a more or less specific chemical nature. It has been termed "contact organization" (Huxley, 1935a) and "evocation" (Needham, Waddington, and Needham, 1934). The second (differentiation within a field) is indirect, and is in all likelihood dynamic. It has been termed "distance organization" and "individuation." Again, inductions are partial processes which depend upon localized "formative stimuli." Field differentiations, on the other hand, are organismic or whole processes which take place in orderly patterns and in characteristic sequences. Examples of induction are the production of nervous tissue in ectoderm through stimulation by chorda-mesoderm, and the production of a lens in epidermis through the stimulus of an optic cup. Examples of differentiation within a field are the structurization of chorda-mesoderm itself, and the structurization of a limb bud.

The problem has been extensively discussed as to whether embryonic inductions are "activations," in which the inducing agent merely stimulates and releases competencies already present but latent in the responding material; or are they "instructions" (to use Weiss', 1935, term), in which the agent also controls, to a greater or less extent, the specific nature of the response. There is evidence to

support both viewpoints. Embryonic inductions appear to be, to varying degrees, mutual affairs involving specific action on the part of both the "actor" and the "reactor." Huxley (1935b) has anyalzed activation further into "local activation," in which the stimulus is some local chemical influence, and "distance activation," in which the agent is a chemical messenger or hormone. The latter may either migrate by diffusion, or be transported in body fluids.

It should be pointed out, however, that in all examples of embryonic induction, a state is involved on the part of the responding material which is intermediate between the possession of a mere possibility and the possession of a definite power or efficacy. Some degree of "competence" must of necessity be present in the material acted upon, some incomplete state of determination, if the inducing agent is to have an effect. Now, this "competence" or imperfect determination is itself of epigenetic origin, having developed through processes of structurization (differentiation within a field; organization followed by invisible differentiation) in the manner which we have described. The inducing agent acts only to perfect a determination already present, to release a competence, to "activate" a "potency."

Now what are the criteria of the several phases of structurization?

A. The tests of *organization* are the properties of the gradient-field, as already listed. A useful method of studying the field is that of the environmental differential. A thermal gradient, for example, may be made to pull a field strongly in one direction (toward the warmed side) and so reveal the extent to which the field is plastic and free, and the extent to which it is anchored in differentiated materials (Gilchrist, 1935).

B. The test of invisible differentiation is the capacity of a part to self-differentiate as a part. Now, of course, there may exist, as we have already hinted, varying degrees of this capacity; and in general the power for self-differentiation increases with time (Gilchrist, 1933). At first differentiations are dependent both for their origin and for their maintenance upon the gradient-field. If the field be modified or destroyed, the pattern of differentiation is altered, reversed, or wiped out altogether. For this reason "weak" experiments, such as minor injuries or defects to the developing egg which do not greatly alter the field, are able to reveal capacities for self-differentiation from the earliest stages of invisible differentiation. But gradually the potential rudiments become more and more stable, until in time only the very "strongest" experiments, e.g. explantations and transplantations, are able to wipe out or modify the field and so alter the course of differentiation. In short, the capacity for self-differentiation as revealed by weak experiments is evidence that invisible differentiation has begun; regulation following strong methods of experimentation is evidence that it is still in progress.

Invisible differentiation may be present to varying degrees in space as well as in time. The central area of a potential rudiment is commonly a "center of intensity" (Spemann; Lehmann, 1928), in which the process of differentiation has progressed furthest and has become most stable. Around this center there is a bordering zone in which invisible differentiation is still reversible. Around this in turn, there may be a larger area which by invisible differentiation has become "competent" to produce the organ in question, but only when sufficiently stimulated. Thus, to take a single example, the limb bud of an amphibian embryo contains a

"central limb disc" which is invisibly differentiated to form a limb, and is, in fact, more or less irreversibly differentiated to do so (Hollinshead, 1932). About this inner area is a zone (the outer regions of the limb bud) which has not gone so far in invisible differentiation. Any part of this region may form a limb, or a part of a limb, or it may not form a limb at all. What it does depends upon the position in which it is placed (Harrison, 1918; Swett, 1927). Finally, outside of the limb bud, there is an extensive territory which includes most of the flank of the embryo, which normally will not form a limb even when a piece of the territory is transplanted to the limb area; but if a spot within this territory be sufficiently stimulated, as for example by implanting next to it a developing ear vesicle or even a foreign object, it may respond by producing a limb (Balinsky, 1933). This competence of flank mesoderm to produce supernumerary limbs when sufficiently stimulated persists long after the embryonic stages are past (Guyénot and Schotté, 1926).

C. The test of visible differentiation is the appearance of more or less sharply defined and delimited areas of morphogenetic activity.

How, by way of conclusion, does this analysis of structurization relate itself to our problem as to whether organic wholeness is gestalt or history? Very simply. *Organization is gestalt.* The gradient-field is labile and self-adjusting like a candle flame. It has always the aspect of wholeness, and it ever tends to an equilibrium within itself and with its surroundings. *Invisible differentiations, are history.* They are straight-forward and creative processes. Like the skyrocket they burst into a pattern and finally fade away. Like a flower bud they unfold into a blossom, and an injury to the bud results in imperfection in the blossom. The organism is both gestalt and history because in the process of its making it undergoes both organization and differentiation.

As students of regeneration we have been concerned largely with processes of organization. We have cut the living material into various patterns and have exposed it to the environment in various ways in order to see how far it will adjust itself to the unnatural conditions. As our reward we have witnessed the plastic flame of the gradient-field adapting itself to form and forces. As experimenting embryologists we have observed for the most part the processes of invisible differentiation. We have taken material already in process of development and have operated upon it. As a result we have seen the increasing evidence of its specialization, and have been impressed with the straight-forward and irreversible nature of the ontogenetic process. As students of the life cycle we also have witnessed progressive changes in the structural pattern. Finally, as students of genetics and evolution, we have studied, for the most part, the more superficial variations which are related to visible differentiation. As a result we have lost sight of the more fundamental problems of localization in time and space which are involved in organization and in invisible differentiation (cf. Lillie, 1927).

Now, both viewpoints, the gestalt and the historic, are but abstractions from the total process of development. The organism is neither pure gestalt nor true history, because it is both. It is first of all a self-regulating system or gestalt, because within its substance there lives a simple, labile, and unified field or flame. It is secondly irreversible history, because within this field localized processes of differentiation take place, and an ever-increasing manifoldness and stability are created.

LIST OF LITERATURE

ABELOOS, M. 1930. Recherches expérimentales sur la croissance et la régénération chez les planaires. *Bull. Biol. Fr. Belg.*, 64: 1–140.

BALINSKY, B. I. 1933. Das Extremitätenseitenfeld, seine Ausdehnung und Beschaffenheit. *Arch. Entwmech.*, 130: 704–746.

BAUTZMANN, H. 1926. Experimentelle Untersuchungen zur Abgrenzung des Organisationszentrums bei *Triton taeniatus*. *Arch. Entw-mech.*, 108: 283–321.

BERGSON, H. L. 1913. Creative Evolution. *New York*. 407 pp.

BERRILL, N. J. 1935. Cell division and differentiation in asexual and sexual development. *Jour. Morph.*, 57: 353–427.

BERTALANFFY, L. VON; trans. by J. H. WOODGER. 1933. Modern Theories of Development. An Introduction to Theoretical Biology. *London*. 204 pp.

BIERENS DE HAAN, J. A. 1913. Über homogene und heterogene Keimverschmelzung bei Echiniden. *Arch. Entw-mech.*, 36: 420.

BURR, H. S., and F. S. C. NORTHROP. 1935. The electrodynamic theory of life. QUART. REV. BIOL., 10: 322–333.

CHILD, C. M. 1907. Analysis of form-regulation in *Tubularia*. V. Regulation in short pieces. *Arch. Entw-mech.*, 24: 285–316.

—— 1915 a. Senescence and Rejuvenescence. *Chicago*. 481 pp.

—— 1915 b. Individuality in Organisms. *Chicago*. 213 pp.

—— 1924. Physiological Foundations of Behavior. *New York*. 330 pp.

—— 1927. Modification of polarity and symmetry in *Corymorpha palma* by means of inhibiting conditions and differential exposure. *Journ. Exp. Zool.*, 47: 343; 48: 197.

—— 1928. The physiological gradients. *Protoplasma*. 5: 447–476.

—— 1929. Physiological dominance and physiological isolation in development and reconstitution. *Arch. Entw-mech.*, 117: 21–66.

—— 1932. Determination of new axes by lateral grafts and incisions in *Corymorpha* in relation to the gradient and dominance. *Physiol. Zool.*, 4: 593–627.

CONKLIN, E. G. 1898. Cleavage and differentiation. *Biol. Lect. Wood's Holl.* 1896–1897: 17–43.

—— 1905. Mosaic development in ascidian eggs. *Journ. Exp. Zool.*, 2: 145–223.

DARWIN, CHARLES. 1875. The Variation of Animals and Plants under Domestication. 2nd edition. Chapt. 27. "Provisional hypothesis of pangenesis."

DETWILER, S. R. 1933. On the time of determination of the antero-posterior axis of the forelimb in *Amblystoma*. *Journ. Exp. Zool.*, 64: 405–414.

DEVRIES, HUGO. 1889. Intracellular Pangenesis. *Jena*.

DOBZHANSKY, TH. 1936. Position effects on genes. *Biol. Rev.*, 11: 364–384.

DRIESCH, HANS. 1897. Studien über das Regulationsvermögen der Organismen. 1. *Arch. Entw-mech.*, 5: 389.

—— 1900a. Die isolierten Blastomeren des Echinidenkeimes. *Arch. Entw-mech.* 10: 361.

—— 1900b. Studien über das Regulationsvermögen der Organismen. 4. *Arch. Entw-mech.*, 10: 411.

—— 1902. Studien über das Regulationsvermögen der Organismen. 6. Die Restitutionen der *Clavellina lepadiformis*. *Arch. Ent-mech.*, 14: 247–287.

—— 1908. The Science and Philosophy of the Organism. Vol. 1. *London*. 329 pp.

DÜRKEN, BERNHARD. 1928. Lehrbuch der Experimentalzoologie. Experimentelle Entwicklungslehre der Tiere. *Berlin*. 782 pp.

FANKHAUSER, G. 1930. Die Entwicklungspotenzen diploidkerniger Hälften des ungefurchten Tritoneies. *Arch. Entw-mech.*, 122: 671–735.

FRAPS, R. M., and MARY JUHN. 1936. Developmental analysis in plumage. III. Field functions in the breast tracts. *Physiol. Zool.*, 9: 378–406.

GILCHRIST, F. G. 1928. The effect of a horizontal temperature gradient on the development of the egg of the urodele, *Triturus torosus*. *Physiol. Zool.*, 1: 231–268.

—— 1929. The determination of the neural plate in urodeles. QUART REV. BIOL., 4: 544–561.

—— 1933. The time relations of determinations in early amphibian development. *Journ. Exp. Zool.*, 66: 15–51.

—— 1935. Prospect and potency in a urodele blastula subjected to a transverse thermal differential. *Anat. Rec.*, 64, Supl.: 45.

—— 1937. The hydroid polyp *Corymorpha palma* as gestalt and as history. *Am. Nat.*, 71: 382–403.

—— 1937. Budding and locomotion in the scyphistomas of *Aurelia*. *Biol. Bull.*, 72: 99–124.

GUYÉNOT, E., et O. SCHOTTÉ. 1926. Démonstration de l'existence de territoires spécifiques de régénération par la méthode de la déviation des troncs nerveux. *C. R. Soc. Biol. (Paris)*, 94: 1050.

HARRISON, R. G. 1918. Experiments on the devel-

opment of the fore limb of *Amblystoma*, a self-differentiating equipotential system. *Jour. Exp. Zool.*, 25: 413–461.

HARRISON, R. G. 1921a. On the relations of symmetry in transplanted limbs. *Jour. Exp. Zool.*, 32: 1–136.

—— 1921b. Experiments on the development of the gills in the amphibian embryo. *Biol. Bull.*, 41: 156–171.

HIS, W. 1874. Unsere Körperform und das physiologische Problem ihrer Entstehung. *Leipzig.*

HOLLINSHEAD, W. H. 1932. Determination of potencies in the forelimb of *Amblystoma punctatum*. *Jour. Exp. Zool.*, 63: 457–482.

HOLTFRETER, JOH. 1934. Über die Verbreitung induzierendes Substanzen und ihre Leistungen in Tritonkeim. *Arch. Entw-mech.*, 132: 307–383.

HÖRSTADIUS, SVEN. 1935. Über die Determination im Verlaufe der Eiachse bei Seeigeln. *Pubbl. della Staz. Zool. di Napoli*, 14: 251–429.

HUXLEY, J. S. 1924. Early embryonic differentiation. *Nature*, 114: 276–278.

—— 1926. Studies in dedifferentiation. VI. Reduction phenomena in *Clavellina lepadiformis*. *Pubb. della Staz. Zool.* (*Naples*), 7: 1–35.

—— 1935a. The field concept in biology. *Trans. on the Dynamics of Development* (*Moscow*). 10: 269–289.

—— 1935b. Chemical regulation and the hormone concept. *Biol. Rev.*, 10: 427–441.

HUXLEY, J. S., and G. R. DE BEER. 1934. The elements of experimental embryology. *Cambridge*. 514 pp.

HUXLEY, THOMAS H. 1879. The Crayfish: An Introduction to the Study of Zoology. *London*.

KINGSBURY, B. F. 1922. The fundamental plan of the vertebrate brain. *Jour. Comp. Neur.*, 34: 461–491.

KÖHLER, W. 1927. Zum Problem der Regulation. *Arch. Entw-mech.*, 112: 315–332.

LEHMANN, F. E. 1928. Die Bedeutung der Unterlagerung für die Entwicklung der Medullarplatte von Triton. *Arch. Entw-mech.*, 113: 121–170.

LILLIE, F. R. 1927. The gene and the ontogenetic process. *Science*, 66: 361–368.

—— 1929. Embryonic segregation and its rôle in the life history. *Arch. Entw-mech.*, 118: 499–533.

LOEB, JACQUES. 1916. The Organism as a Whole from a Physicochemical Viewpoint. *New York*. 379 pp.

MANGOLD, O. 1923. Transplantationsversuche zur Frage der Spezifität und der Bildung der Keimblätter. *Arch. Entw-mech.*, 100: 198–301.

MARX, A. 1925. Experimentelle Untersuchungen zur Frage der Determination der Medullarplatte. *Arch. Entw-mech.*, 105: 20–44.

MILOJEVIĆ, B. D. 1924. Beiträge zur Frage über die Determination der Regenerate. *Arch. Entw-mech.*, 103: 80–94.

MORGAN, T. H. 1901. Regeneration. *New York*. 316 pp.

NÄGELI, C. 1884. Mechanisch-physiologische Theorie der Abstammungslehre. *München u. Leipzig.*

NEEDHAM, J., C. H. WADDINGTON, and D. M. NEEDHAM. 1934. Physico-chemical experiments on the amphibian organizer. *Proc. Roy. Soc.*, B 114: 393.

NICHOLAS, J. S. 1924. Regulation of posture in the fore limb of *Amblystoma punctatum*. *Jour. Exp. Zool.*, 40: 113–159.

PENNERS, A., und W. SCHLEIP. 1928. Die Entwicklung der Schultzeschen Doppelbildungen aus dem Ei von *Rana fusca*. *Zeitsch. wiss. Zool.*, 130, 305–454; 131, 1–156.

PRZIBRAM, HANS. 1929. Experimental-zoologie. VI. Zoonomie.

RABL, C. 1906. Über "organbildende Substanzen" und ihre Bedeutung für die Vererbung. *Leipzig.*

RAND, H. W. 1900. The regulation of graft abnormalities in *Hydra*. *Arch. Entw-mech.*, 9: 161–214.

—— 1924. Inhibiting agencies in ontogeny and regeneration. *Anat. Rec.*, 29: 98–99.

RAVEN, C. P. 1935. Zur Enwicklung der Ganglienleiste. IV. Untersuchungen über Zeitpunkt und Verlauf der "materiellen Determination" des präsumptiven Kopfganglienleistenmaterials der Urodeleneier. *Arch. Entw-mech.*, 132: 509–575.

ROUX, W. 1883a. Über die Bedeutung der Kernteilungsfiguren. *Leipzig.*

—— 1883b. Über die Zeit der Bestimmung der Hauptrichtungen des Froschembryo. *Leizig.*

—— 1905. Die Entwickelungsmechanik: ein neuer Zweig der biologischen Wissenschaft. *Vortr. und Aufs. ü. Entw-mech.*, 1.

RUDY, H. 1931. Die biologische Feldtheorie. *Abh. z. theor. Biol.* (Schaxel), 29. 64 pp.

SCHAXEL, J. 1922. Über die Natur der Formvorgänge in der tierischen Entwicklung. *Arch. Entw-mech.*, 498–525.

SHARP, L. W. 1934. An Introduction to Cytology. 3rd Edition. *New York*. 567 pp.

SPEMANN, HANS. 1918. Über die Determination der ersten Organanlagen des Amphibienembryo. I–VI. *Arch. Entw-mech.*, 43: 448–555.

—— 1919. Experimentelle Forschungen zum Determinations- und Individualitätsproblem. *Naturwis.*, 7: 581–591.

SPEMANN, H., und B. GEINITZ. 1927. Über Induktion von Embryonalanlagen durch Implantation artfremder Organisatoren. *Arch. Entw-mech.*, 100: 599–638.

SPEMANN, H., und HILDE MANGOLD. 1924. Über Induktion von Embryonalanlagen durch Implantation artfremder Organisatoren. *Arch. Entwmech.*, 100: 599–638.

SPENCER, HERBERT. 1866. The Principles of Biology. *New York.*

STEINMANN, P. 1927. Prospektive Analyse von Restitutionsvorgängen. II. Über Reindividualisation, d. i. Rückkehr von Mehrfachbildungen zur einheitlichen Organisation. *Arch. Entwmech.*, 112: 333–349.

STOCKARD, C. R. 1921. Developmental rate and structural expression: An experimental study of twins, "double monsters," and single deformities, and the interaction among embryonic organs during their origin and development. *Amer. Jour. Anat.*, 28: 115–266.

STOLTE, H. A. 1936. Die Herkunft des Zellmaterials bei regenerativen Vorgängen der wirbelosen Tiere. *Biol. Rev.*, 11: 1–48.

SWETT, F. H. 1927. Differentiation of the amphibian limb. *Jour. Exp. Zool.*, 47: 385–439.

TAYLOR, C. V. 1935. Protoplasmic reorganization and animal life cycles. *Biol. Rev.*, 10: 111–122.

TENNENT, D. H., C. V. TAYLOR, and D. M. WHITAKER. 1929. An investigation of organization in a sea-urchin egg. *Carnegie Inst. of Wash.* Publ. 39. 104 pp.

TÖNDURY, GIAN. 1936. Beiträge zum Problem der Regulation und Induktion: Umkehrtransplantationen des mittleren Materialstreifens der beginnenden Gastrula von *Triton alpestris*. *Arch. Entw-mech.*, 134: 1–111.

TREMBLEY, 1774. Mémoires pour Servir a l'Histoire d'un Genre de Polypes d'Eau douce. *Leide.*

TYLER, ALBERT. 1933. On the energetics of differentiation. (I) A comparison of the oxygen consumption of "half" and whole embryos of the sea-urchin. *Pubbl. d. Staz. Zool. (Naples)*, 13: 155–161.

TYLER, ALBERT. 1935. On the energetics of differentiation. II. A comparison of the rates of development of giant and normal sea-urchin embryos. *Biol. Bull.*, 68: 451–460.

VOGT, W. 1924. Morphologische und physiologische Fragen der Primitiventwicklung. *Sitz. Ges. Morph. u. Physiol., München.*, 35: 22–32.

—— 1927. (Aussprache zu W. Brandt.) *Anat. Anz.*, 63, Erg-h.: 24–35.

WADDINGTON, C. H. 1932. Experiments on the development of chick and duck embryos cultivated in vitro. *Phil. Trans. Roy. Soc. (London)*, B 221: 179–230.

WADDINGTON, C. H., and G. A. SCHMIDT. 1933. Induction by heteroplastic grafts of the primitive streak in birds. *Arch. Entw-mech.*, 128: 522–563.

WEISMANN, A. 1893. The Germ-plasm. *New York.*

WEISS, PAUL. 1926. Morphodynamik. *Abh. d. theor. Biol.* (Schaxel), 23. 43 pp.

—— 1933. Functional adaptation and the rôle of ground substances in development. *Amer. Nat.*, 67: 322–340.

—— 1935. The so-called organizer and the problem or organization in amphibian development. *Physiol. Rev.*, 15: 639–674.

WHITMAN, C. O. 1878. The embryology of *Clepsine*. *Quart. Jour. Micr. Sci.*, 18: 215–315.

—— 1894. The inadequacy of the cell-theory of development. *Biol. Lect. Wood's Holl.*, 1893: 105–124.

WILSON, E. B. 1894. The mosaic theory of development. *Biol. Lect. Wood's Holl.*, 1893: 1–14.

—— 1905. The problem of development. *Science*, N. S., 21: 281–294.

WITSCHI, EMIL. 1934. Genes and inductors of sex differentiation in amphibians. *Biol. Rev.*, 9: 460–488.

WOODGER, J. H., 1929. Biological Principles. *London.*

THE SEVENTEEN YEAR CICADA, ALIAS LOCUST

By E. A. ANDREWS

Department of Zoology, Johns Hopkins University

INTRODUCTION

THE cicadas, mistakenly called locusts, are preëminently noise-makers so that a famous naturalist, more than a century ago, called them not cicadas but stridulantes and cantatrices. It was they who invented their forerunner of the Claxon horn, a stiff membrane to be knicked back and forth—quite a different noise-maker from that possessed by any other animal.

When the song birds depart and the silence of winter falls upon us we long for their return even though the morning songs may awaken us too early; but few who recently experienced the day-long racket of the periodical cicada, or locust, will regret that they must wait some seventeen years before hearing them here again in full cry.

All over the warmer regions of the earth there are more than a thousand kinds of cicadas; in New Zealand, Australia, Asia, South and North America and in southern Europe, where, along the shores of the Mediterranean they formed part of the daily lives of the Greeks and Romans. Everywhere the noises made are different for the different kinds, and everywhere man's names and ideas associated with these insects have stressed the sounds that envelop them as a halo.

Much curious lore bearing on the sounds of cicadas is to be found stored up in a book of Myers upon these insect singers. Again it was the sounds of the cicadas that impressed Professor T. H. Huxley when as a very young naturalist he visited Rio, Brazil, in February 1847, for he wrote—"There are two things that forcibly strike anyone going into the country here, first the enormous number, variety and beauty of the butterflies and second the noise of the cicadas. These fellows are as big as a man's thumb and fly about the trees like locusts. They emit a very loud continuous note, and when numbers of them are together it is really deafening. Singularly enough they seem to agree to short intervals of silence, then the note begins, at first weakly, then swelling into a grand chorus and gradually dying away again."

Yet while noise is the essence of the cicada as part of the web in man's history, the cicada after all, is phenomenally quiet through most of its life, since all these kinds of cicadas live underground one or more years and limit their utterances to the few brief months of their life in the sunshine before they died of old age, having left concealed eggs to live after them. Even at the peak of garrulous old age only half of the cicadas are to be heard, since only the males specialize in this rejoicing after the long silent life underground. This was long ago expressed by the poet of classical times:

> "Happy the cicadas' lives
> Since they all have silent wives."

On the other hand the real locust is a sort of grasshopper that makes contact with human kind not so much by any noise it may make as by its ability to devour plants that man needs. A long subterranean life is foreign to the real locust, which leaves the earth as soon as

it hatches from the egg and spends the rest of its life up in the sunshine.

The two are built upon quite different models; the locust with its long slender body with head hanging like that of a horse and powerful jaws to nibble leaves: the cicada of triangular outline, with wings as sides and head as broad base bearing the eyes astonishingly far apart, so that the face resembles that of its gnome-like relatives the "treehoppers." This cicada shows no biting jaws but only a sucking beak, like a true bug, able only to puncture and suck. The locust has often proved a serious threat to man's subsistence: the cicada has chiefly proved an interesting annoyance. That both may congregate in great numbers is the chief resemblance between these two diverse insects. The span of life of our seventeen year cicadas being about one-fourth that of man, to whom has been allotted three score years and ten, few can say as did the contributor to *Insect Life* that he had heard the cicadas in one spot five successive periods of eruption, namely, 1817, 1834, 1851, 1868, 1885. Others there were who heard them there in 1902, 1919, 1936—and in the future?

Many there are who will be laid in the earth before these cicadas emerge again—let us hasten to record our contacts with the cicadas of this period. The following observations and considerations refer to an area of a couple of acres, as one of the many showing cicada phenomena in the north edge of Baltimore, Md. Here the cicadas still hold their own as did their ancestors when the occasional Indian was the only man to listen to them before the white man came to claim the cicada's land as his own.

THE LIFE UNDERGROUND

Knowledge of the life of the cicada under ground is replete with surmises and inferences, but direct observations are difficult and not numerous. The slender little white young are seen to enter the ground and seventeen years later the stout, inch-long cicadas, looking rather like peanuts on legs, are seen to come out of the earth and to transform into winged adults. Just what happens all those years? The entomologists in Washington planted the young, like seeds, and year by year dug up successive crops of growing cicadas. Evidently like other insects these underground creatures grow in steps, each time casting off the outer stiff cuticle to expand. Six such steps were found, each a few years apart.

In many insects the egg gives rise to creatures so unlike the adults that they seem rather like worms and we call them larvae, but in others the young have more resemblance to the adult and we call them nymphs; this latter is what we find in the cicada where all the young have legs and beaks much like those of the adults. Again many insects pass into a resting stage in which they may seem nearly dead—the pupa stage, from which the adult arises as if by a rebirth. In the cicada the pupa shows already outlined the wings it will have as adult. Of the six nymph stages dug from the earth four lack wing-pads and are mere larva-like nymphs while the next following two stages show wing-pads and are pupa-like nymphs. However these so-called pupa stages in the cicada are active workers, and by no means like the inert pupas of higher insects. In the first year under ground the young are not deep down but later they go to a depth of two feet and more. The nine year old nymphs we dug up in October 1928 were about one-half inch long and found at the depth of two feet.

Marlatt discovered that the successive young stages differ not only in size but in the details of their digging claws and, interestingly, the tips of these claw legs that are of more use in walking than in digging dwindled away at successive moults till about lost, but then, when the young was preparing to come forth to walk, that is in the two pupal stages, this tip came back again in style, along with the wing-pads and the distinct external sex organs that show on the pupa.

We find the insect enters the earth weighing but a third of a milligram when a bit over a sixteenth of an inch long. Eventually it comes forth weighing 1000

milligrams and well over one inch in length. Whence this 4000-fold increase in volume and 3000-fold increase in weight? We find these cicada nymphs close to roots and as they always have good sucking tubes they no doubt act like their relatives, the "treehoppers," "the plant lice" and the "scale insects" and suck juice from roots of trees and bushes. Under a maple tree they may be said to feast upon maple syrup. If like their above mentioned relatives these cicadas drink excessive sugar sap to gain some protein also, they may, like those other insects, pass off an excess of water, sugar and dextrin. That would be like the honey-dew of the above insects, which ants and other insects profit from.

But underground we know no insects to profit by such excess, if there be any discharged by the cicadas, and we can only guess as to its use. Apparently the cicada down below has neither friends nor foes and it must lead a life of a "shut-in" with earth and roots as the chief elements in its world. Its chief companion in the subsoil may be the resting earthworm in its tight coil of pink pulchritude. Day and night, even summer and winter, present to the cicada nymph no such contrasts as are forced upon animals above. This isolation has its advantages, living in a rather uniform temperature with food and water at hand, the cicada is free from the attacks of the innumerable insects, fishes, amphibia, reptiles, birds and mammals that decimate the hordes of insects in the waters, in the air, and on the surface of the earth. Even the voracious mining moal may rarely descend to the cicada level. How much does the cicada know of the winter? It may well cease to feed when shedding its shell every few years; but does it rest, or feed, during the winter? Some considerations lead one to assume that our cicadas may not feed in the winter. Thus while cicadas generally live in warm climates our seventeen year kind not only survive the northern winter but also live longer than others in warmer countries.

Moreover, there is a variety in the southern states that needs but thirteen years to attain maturity, as if gaining time when less hampered by cold winters. The above is one of the many questions waiting for experimental evidence. Another is, what does the cicada do when the earth is soaked with rain? Another relates to the possible journeys of cicadas underground. The young falling from the tips of branches should enter the ground near the tree, unless blown away by winds, but when they emerge from the earth in after years they may be far out beyond the tips of branches where only roots extend and so we may infer some journeyings under the earth in long years. Also we find them emerging under porches and roofs where they could not have fallen but must have arrived by migration, probably underground. But do they wander far, from one tree to another? What happens to them when their tree is cut down or killed? Experiments are needed here. If some wander others stay restricted to the same spots, for we found them emerging under the same tree in 1919 and 1936 and under other trees in 1885 and 1902. How long the cicadas may continue to attack one tree is yet to be determined but evidently in the course of time trees will die of old age before the cicada clan is wiped out, and so the cicadas that once occupied the land must have migrated from the trees of then to the trees of now. Their gradual spread over the country was likely by short flights and by creeping on earth rather than by any subterranean migrations. Hence to assume with a Baltimore poet that these cicadas are doomed to wander in the earth

from Baltimore back to the scene of Pharaoh's plagues is an interesting extension of the common misbelief that these Cicadas of Baltimore derive from the locusts that vexed Pharaoh.

"Must thy doomed race impelled by mandate stern,
Traverse the earth's interior and return?"

THE SHAFTS

Digging for cicadas we may find them each within a small mud cell but we fail to see a system of levels and drifts like the borings of many insects in wood. We assume the works are largely horizontal passages of the nature of "stopes" as being soon filled in and not kept open.

However, there comes a time when the miner changes his low life and seeks to ascend to the air above. Now begins the shaft that each and every cicada makes for itself as a means of escape from the dark earth to the realm of light. Each is slowly dug out as a wide well from a foot down up close to the surface where it remains closed for a long time. The cicada is seen working in April of the year it will emerge but in some cases we thought it was working even two or three years before it emerged. This shaft is a work of great labor and more elaborated than a mere passage-way by which to escape. The creature is now in the pupa stage and its activities are aimed toward the final transformation into the winged adult. The upper part will serve as a resting chamber for the pupa till emergence is in order. But there are two other facts about the shaft that deserve notice. One is, that rarely does a shaft connect with another, though often so close together and thus there come to be very many parallel shafts, as in the work of shipworms in wood, and here also we infer the worker must have some method of finding out where the neighboring shafts are situated and this same method may be of use to the cicada when it comes near the surface of the earth and is not yet ready to break through the last thin layer that separates its shaft end from the air above. The second fact is that emphasized by that phenomenal naturalist, Fabre: namely, that the cicada begins the shaft below and ends it near the surface without there being any evident material thrown out or visibly stored away. So many cubic inches of earth excavated to make a shaft, but no earth dump to be found!

While so many earth burrowing animals begin at the surface and throw out the earth, or even carry it away and scatter it so that the burrow is not so easily detected, the cicada begins below, it may be in the dense subsoil where there is no space to store the excavated earth. Fabre explains the mystery in the case of the cicadas he studied in France by assuming that they wet the earth and by force push it back through the walls, so that, we assume, the fine suspension would fit in between the particles and displace the air. An examination of the shafts here in Maryland shows some reason for accepting some such explanation. The shaft has a lining of about one-eighth inch thickness that grades off into the outer earth but is internally fine earth showing flow marks as if deposited when very soft. These walls keep intact for months after the cicada has left and stand as finger wide holes firmly lined. Where the shaft is in subsoil the lining is subsoil and where in topsoil it is topsoil, so that we infer the lining is made locally and not of material carried far. The cicada nymph is very moist when dug out and seemingly full of liquid that might well furnish the needed moisture to the walls. Fabre supposes each cicada has its root from which to take moisture and to which it may return as the shaft advances. He also surmises

the moisture taken in is run through the digestive tract and the surplus used in irrigating. Snodgrass put some of our shaft building cicadas into glass tubes and saw them picking the earth loose with their claws, raking it together, grasping it in their claws and shoving it into the walls of the shaft—but this was in loose earth.

Strange to say when the cicada comes near the surface of the earth it stops abruptly and rests for many days before breaking through to the air. During that time the top of the shaft ends in a carefully made arched dome with a thin layer of the natural earth surface above it. Thus the shaft is not visible at all, yet bluejays and other birds now search for the inmates and one wonders if sometimes the inmate may peek out before emerging and thus see and be seen. The inmate may be resting just beneath the domed end but it is hard to capture since, though a pupa, it is very keen to escape, crawling down, or dropping down, its shaft when disturbed.

In April the sun heats the surface of the earth and the cicada resting for weeks just below may well experience more warmth than it has had for very many years and this may be of great consequence. When the shaft happens to come up under a board or other opaque object the cicada often turns its shaft and makes a tunnel along horizontally till it comes to the edge of the obstacle. Here there is careful building of walls though the roof of the tunnel may be in part the overhanging board.

Another form of this extension of the shaft is frequently seen in dense shade as under hedges, porches, buildings, low branched shrubbery, overturned boxes and high thick grass; regions where it is dark and also where the sun does not shine to warm the surface. This shaft extension is the chimney or turret so much like that made by the crayfish, but smaller. The chimney is over an inch wide and up to five inches high, made of soft mud applied in particles and capped above with mud that inside is the usual dome that ends the shaft, for the cavity of the chimney is but the extension of the shaft above ground. In places these chimneys are exceedingly numerous and as they are often where protected from weather they last for months as little unbaked clay tubes, closed at the end till the cicada comes out there.

It is to be emphasized that generally these chimneys stand out as being made of light colored subsoil and not of topsoil and thus they were made of material brought from below where in April the water table may be high. When in 1902 we put shaft builders in glass receptacles with earth we saw them bring wet earth from below in the following strange fashion. The head of the cicada as nymph is like a wedge as if to penetrate the earth, or something like the "cowcatcher" of an old fashioned locomotive. These captive cicadas had mud plastered on the right and left cheek of this face when they struggled up the shaft to then wipe off the mud, with their large clumsy claws. Thus little hodfulls of mud were carried up to build the chimney, but here the mud was carried on the outside of the hod-like head.

In 1919 Snodgrass added to our meager knowledge of the cicada shafts by pouring plaster of Paris down the shafts and so discovered that all the lower parts were filled in with dark refuse while only the top of the shaft was kept open and of use. In fact many shafts were but little chambers close to the surface, though others went down six inches as patent holes somewhat enlarged both above and below, so that the inmate had opportunity to rest either close to the surface of the earth or else down some inches in the earth.

But it would be an error to assume from these findings of Snodgrass that all the

cicadas' shafts as antechambers to the upper world, are restricted to the upper six inches of soil. In the first place when the earth is dry and hard in September the holes left by the cicadas are still patent and by simply sounding them with straw or twig we find at once that they go down nearly straight, often but three inches but often more than six inches, eight being common and nine found here and there, while two had a clear passageway for ten inches and one for eighteen. These measurements were made under apple, pear, cherry, beech, mulberry, maple, oak, tulip, sassafras, arbor vitae and dogwood trees and under old English box, California privet and Japanese barberry bushes.

Now when we poured in plaster of Paris and excavated we found that some of the shafts went to a depth of fifteen inches, as an extreme. The casts showed the slender neck at the surface where the cicada broke through the roof but did not show any special enlargement of the shaft just beneath the surface as the shaft was about of uniform diameter from just beneath the surface to the lower end.

The bottoms of the shafts, as casts, were enlarged and the little chamber so formed was generally to one side, so that the end of the cast looked like a leg ending with a club foot. Noticeably the bottoms o-these end chambers were flat and horif zontal so that the cicada might be supposed to stand resting there at ease before climbing up to investigate surface conditions. A cluster of such casts carefully washed free of soil presents somewhat the appearance of a group of stalactites of cylindrical form, but sinuous, and often ending below in an irregular enlargement and then rising about forty-five degrees for a few inches before becoming more nearly perpendicular. Some are smaller and some larger and though often very close together they do not touch one another.

In this case all the casts were in the topsoil, here about a foot deep, and when the casts and soil were removed the hard clay subsoil did not show any continuation of the shafts downward. Only here and there a few earthworm burrows lined by dark earth led down into the compacted subsoil. While the finer roots ran about amidst the casts the larger roots were chiefly below the bottoms of the casts. However there was no evident association or contact between roots and casts.

While digging the cast on September 7, we found several remains of cicadas, in four by four feet of topsoil; cicadas that as pupae did not succeed in emerging from below. Also two living pupae were found still down in the earth: like Rip Van Winkles that awoke so late!

These shafts seem the work of the cicadas in their last year or years under the earth; what excavations were made before and how the shaft was begun are samples of the many questions to be answered in some future.

The pupa stage in many insects is so inert as to need special protection by some case or cavity and these open tops of the shafts supply the cicadas with the protection of a pupal case, while also leaving these active pupae the chance to emerge when ready. In these chambers the cicadas are at the mercy of rooting hogs and many fall a prey to birds if they are not quick enough to fall down to their lower retreats. In seeking for a compensating advantage in these carefully made chambers we conceive that the chamber near the surface supplies the cicada with the needed moisture and temperature and modicum of protection to enable it to complete its "ripening" for the time of next shedding, to attain the final phase.

If it could be shown that the sunshine

as warmth is needed to "ripen" the cicada we would add one more to the attempts to explain the chimneys that arise where there is little sunshine; namely, that the cicada digs upward till attaining the right dryness and warmth, and if this is not found at the surface, as when under a board or in dark shade, then proceeds to build up with carried mud, as seeking the warmth and dryness that will quiet its digging tension.

The shaft with its upper antechamber to the world of light is the chief engineering and muscular labor of each cicada, as under-earth creature. The shaft is as wide as half the cicada's length and may have a length fifteen times the length of the cicada that made it. Compared with this, a man of five feet height would dig up from below, without allowing any earth to show, a shaft seventy-five feet long and two and a half feet wide. But such a man should be born a husky infant of five inches length able to dig himself down and stay down till before a few weeks of his death from old age!

EMERGENCE

In the cicada's calendar late May is the season for breaking away from the soil. If we are fortunate enough to be on hand, lying upon the earth, we see a remarkable sight. Where the earth and grass are unbroken there is here and there a faint movement and presently minute holes appear. From each, at length, protrudes the tip of the wedge-shaped head of a cicada and this is often muddy. Appearing and then vanishing it is slowly making a hole through the dome that ends its shaft-chamber above. The soil seems to be moistened. Presently the head with clean eyes and feelers sticks out a bit, and for the first time the eyes may see the new world above. The animal may twist ot one side or the other and may drop down again out of sight, but after some fifteen minutes struggle it manages to jam its body through the small opening it has made and scrambles out onto the earth's surface that it left seventeen years ago. The hole made in the dome is but just large enough for exit and the same is true of the holes seen at the tops of the chimneys so that we fancy the cicadas that emerge from the tops of these chimneys crawl, or fall, down from the tops of the chimneys after having had a chance to see the world from the chimney top. When first seen, and seeing, the cicada may be facing in any direction, but when once outside its hole the cicada seems forced to go in one direction only, namely straight toward the tree it has so long lived with.

The best time to view the emergence from the soil is when daylight is still strong, say between six and seven, for though very many will be popping up much later their exits are then difficult to see. Snodgrass records "At Somerset, in spite of closest scrutiny and long vigils with electric light and lanterns, we were never lucky enough to witness an emergence." However, when we clearly see one or another emerging here or there about a tree we may expect soon to see others peering out even an inch away from the one we are watching and presently it seems as if Gabriel's trumpet had opened up all the little graves round about for the dead to arise.

The emergence is by no means all in one night. Under one large pear tree some 5000 cicadas emerged during thirteen days, first very few, then more to a maximum and then fewer and fewer yet. Other trees showed the same waves of flow, increasing and waning, but trees near together did not ripen their crop on the same days exactly. Some hundred feet apart trees differed near a week and in regions a mile apart the differences were a week or more. In 1919 the emergence under a given tree began May 22 and ended June 4 and in 1936 the first emerged May 21 and the last soon after June 6. That is, under one tree the new generation emerged within the same two calendar weeks as did their parents. The daily emergence has some connection with the sun, it takes place as light fades in the gloaming and on to nine o'clock and later—very rarely in early morning hours.

We cannot suppose the fading light acts on the cicada within its chamber but the dwindling heat of

day may do so and thus give a signal. At all events there is some connection between emergence and temperature for in chilly nights of 40°F. the flow may near cease, to resume when normal temperatures return. However, even if the temperature is one of the signals that makes the cicada act, the chief background for this seasonal emergence is to be sought in the slow changes of seventeen years, leading up to a certain ripeness for response to the sun's behavior.

Just as there are exceptional individuals that emerge a little before the general rush-night and also a few belated ones; so there are some few cicadas that emerge a whole year ahead of or behind the general clan. Yet the unanimity of action on the part of these creatures is most remarkable. And yet each has no communication with its fellows. Each works for itself and emerges upon its own responsibility and not at the bidding of another. Examination and calculation show that where 5000 came from beneath one tree there remained just about as many holes; that is each makes its own hole. Evidently no reformer has convinced the cicada that it were better for a few (others) to build community shafts to be used in common, by those who did not work! At present each does his own work for himself. Hence the holes in the earth are very numerous and lasting on for months after the emergence of their makers, they form a new factor in the soil; as a means of modifying the in and outgo of air, the letting in of rain water, increasing dryness, furnishing shelter and other features for the very numerous little people that one sees wandering through the miniature jungle fashioned by the grass beneath the tree—that is ants, beetles, crickets and other insects along with spiders, mites, isopods, centipedes, snails and earthworms. That these holes may have important rôles to play is suggested by their numbers and long persistence.

Under and near an apple tree we made the following enumeration of these shafts used by the emerging cicadas a month ago. In an area four feet by four feet ten inches were counted 601 holes, a quarter to a half-inch in diameter; about thirty to the square foot. But the distribution was far from uniform; there was a space of six by six in which were no holes while again holes were so crowded that there was but an inch or even half-inch from center to center of closely adjacent holes. Scarcely any were found to open in common and these were separate just below the surface.

Another area of four feet by eight feet two inches yielded 834 holes, or an average of 24 to the square foot. But this included a bare space of ten to twelve inches with no holes, but also in it, close to the tree, where the holes were very large, up to five-eights of an inch, they were crowded to a density of 55 and even 61 to the square foot. Thus may the ground be converted into a veritable sieve by the strenuous work of these creatures seeking escape from below.

This astonishing riddling of the earth is one of the marked aspects of cicada phenomena and early attracted the attention of the white man who knew nothing of the like kind in Europe. Thus in an account made in Virginia in 1675, as recorded in *Insect Life*, vol. 2, pp. 161–2, we read of insects like swarms of flies about an inch long and big as the top of a man's little finger rising out of "spigot holes" in the earth, to eat the new sprouted leaves from the tips of the trees, without other harm: "and in a month left us."

TREK TO THE TREE

The long strenuous labors of the cicadas making shafts is not as easily seen as wondered at, but once the cicadas emerge anyone standing near may easily see another wonder, though it may not be readily understood.

Standing in the region of the emergence we are enveloped with the wave of migration to the tree. Far from the tree cicadas come crawling as fast as they can toward the tree trunk, at first scattered and few, but ever more crowded as they gain recruits and coming into the smaller circles near the tree trunk they finally reach and climb up. On the trunk the noise made by the innumerable feet of the climbing hordes as they grasp the bark is plainly

heard, like the pattering of rain drops. The obstinate persistence of each cicada in making for the tree is most striking: pick it up and tumble it about however much, it does not become confused, but resumes its solemn march to the tree. Take one from the north of the tree where it was going south, and place it south of the tree, then it goes now north, always toward the tree. All about the tree each goes on its own radius, but taken to any other radius it proceeds along that one just as well. It seems as if each cicada were pulled to the tree, as iron to a magnet. The following experience illustrates this strikingly. We stand pointing at the tree with a cicada on our hand and the cicada walks toward our fingers and so continues as we walk all about the tree, aiming itself at the tree as we point at it: but let us face about, with back to the tree, and then the cicada turns through 180 degrees and walks away from our fingers and up our arm; ever toward the tree which is now behind us.

If we watch an area between two large trees we see some go toward the one tree and others toward the other tree as if each knew its own tree. Here again each persists in its own direction no matter how picked up and reversed. What may be the way in which the tree serves as center of attraction for these many cicadas just out of the earth? Is it possible that in seventeen years of experience the cicada gains and holds a sense of where the roots center at the trunk? A simple experiment weakens this supposition. Take cicadas from their home tree, that is the one they have lived with so long, and carry them far away to some tree they have presumably had no knowledge of and they go toward this new tree though they may be going farther away from their own home tree.

These plump cicada nymphs are but clumsy walkers, but each seems most intent upon hurrying as fast as possible, in dead earnest, to get to the tree in time, without however any reference to the others. While to be sure, when hundreds march in open formation toward the tree in droves there is some resemblance to the common action of a swarm of bees entering a new hive, yet here there is no suggestion of these cicadas being led by odors or sounds made by their fellows. That it is really the large red eyes that aid the cicada in finding the tree is a supposition readily made and easily proved to be true. While the cicadas still continue to show good orientation to the tree even when faint light lasts on in the evening, in the darkness of midnight we find them wandering about and going nowhere. However such late walkers are unusual and it might be thought that they were not normal. Cicadas emerging under a maple tree in the midst of dense growths of periwinkle plants, even though they had chimneys, wandered and seldom found the tree, as if they could not see through the dense mass of leaves.

Better indication of the use of the eyes is the following. Cicadas placed on the bottom of an overturned wooded box some five inches high and three feet long and wide, walked across the box toward the distant tree they had not dealt with before and coming to the edge fell off and went on in the grass. When, however, a bushel basket was placed over the cicadas on the box they no longer oriented to the tree but walked off to all sides of the basket. Now human eyes beneath the basket found it possible to see some branches, but not the whole tree, through some slits in the basket, but the eyes of the cicadas failed to be influenced by these part views.

Convincing evidence that the eyes served the cicadas to reach the tree was had when we painted thick red watercolor paint over their eyes as they were marching for the tree. It may be remarked that the insect eye is covered with a hard, inert, shell so that paint on it is like paint on a human finger nail, causing no suffering, unless to the onlooker. Such blinded cicadas ceased to go toward the tree but wandered and went nowhere in particular, but when the paint was

washed off they went again toward the tree with no evident lasting effect of the paint. When only one eye was covered the cicada was still able to orient to the tree very well. On top of the head cicadas have three little simple eyes and whether these were painted, or not painted, seemed to make no difference in the march toward the tree; and this is in harmony with the common impression that such simple eyes are of use only in connection with objects near at hand. If then, the tree enters the cicada through its eyes what do we suppose the tree looks like to the cicada—is it like the tree of the botanist, or of the artist, or what? The distant tree and the tree overhead should seem different, the one being a mass, light or dark, against the evening sky and the other a shadow about a trunk that is darker or lighter. That these cicadas do react to a tree very distant as compared to the one inch length of the insect, was observed in 1919 when they went toward a tall tree seventy feet away, proceeding both upon the grass and upon a table that was turned about to demonstrate the persistence of the cicada in going toward the tree, however often reversed. In 1936 cicadas were seen to start off for a large tree distant 150 feet, under the following circumstances. A piece of plowed ground, 100 by 200 feet surrounded by trees and amongst them one very large tulip poplar in the southwest corner, had in its middle a strip 12 by 40 feet raked and rolled for the cicadas to walk on. At each end of this smooth area there was set up, to represent a tree trunk, a furnace pipe, a foot wide and four feet high, covered with burlap. The one at the north end of the area bore a superstructure of black cloth four feet wide and six high to suggest something of the effect of foliage of a tree above the trunk. The cicadas taken emerging or else already crawling up trees, were taken hundreds of feet to this area and there dumped down in the middle, by fifties and by hundreds.

In several trials May 26 and 27 most all the cicadas walked directly in the direction of the far distant tree and at first few paid any attention to the imitation tree trunks, though so near, but many having started the long trek to the distant tree turned aside and went to the tree stump image, reached it, and climbed it, though others lost themselves in the plowed ground. Again when dumped upon a piece of compo board four by eight feet in size the cicadas at once started for that distant tree and when then the board was turned 180 degrees, with all the cicadas on it, they at once faced about to continue on toward that tree. Then the compo board was set upon end so as to screen the tree from human eye close to the earth, yet when the cicadas were dumped three feet from the board they again went toward the tree and toward the screen that hid it. However, the moon now shone and the board appeared as a shade and this may have influenced the cicadas to move toward it. Strange to say when this board was set up to the north near the tree with imitation foliage and the cicadas dumped three feet in front of it they again went toward the board though this was now bright in the moonlight and the imitation tree was darker. Here, however, we are dealing with responses to nearby objects, and light and shadow near at hand belong with the problem of how the cicada reacts to nearby trees they have actually reached. To simulate such a close-up tree there was set up in place of the above two effigies, May 31 and June 1, one similar trunk surmounted by a horizontal lattice of wood, four by eight feet, and covered with compo board so as to cast a dense shade all about the imitation trunk. When cicadas were put near the edge of this shade many of them paid no attention to it, but marched off toward the big tree 150 feet away. This is similar to what happened in natural conditions when cicadas, emerging under a hedge, left the shade to cross bright grass to reach a distant tree. However other results were got in the rather good daylight from six to seven before the moon was bright, for then often many cicadas preferred the nearby imitation tree to the far distant one, went along all radii to the trunk under the horizontal slats, reached the trunk, climbed up and then out on the slats to transform so successfully that in the morning many shells were found attached to both "trunk" and "branches" as in a real tree, though here were no leaves.

Apparently the intensity of the light is an important factor in orientation. When responding to a real tree cicadas pass from the lighted field into the shadows of the tree and there is then presented to them the trunk, which they reach as if they saw it, for when a large tree was illuminated on one side by a strong street-lamp, cicadas on the light side went to the bright trunk and cicadas on the dark side went to the dark trunk, though in the one case the trunk was bright against a dark background and in the other dark against a bright background.

This same ability to proceed toward a tree whether dark or light is seen when they react to distant trees, that is when they are placed between two large trees each twenty or more feet distant; some go

toward one tree and others toward the other tree, though the one is bright against the darker eastern sky and the other dark against the sunset sky. We infer the tree is to the cicada at least a contrast to the background.

If cicadas are proceeding toward a tree and we turn them clockwise through 180 degrees, each cicada turns itself counter clockwise; and the reverse. This may imply the movement of some sort of image in the eye of the cicada.

The tree influences the cicada through its eyes in such a complex way that we are prone to infer that the tree exists in the cicada somewhat as it does through the human eye; but what the experiments actually show is that the cicada responds to the tree as an area of greater or less light contrasted with the background.

TRANSFORMATION

The long years of slow creeping come to an end up in the tree when transformation sends each cicada forth as a winged creature. The horizontal journey to the tree trunk is followed by adept vertical climbing whether the tree trunk be smooth or rough, but when branches are met there is again horizontal progress, but now upside down along the under face of the branch. Having walked centripetally on the earth the cicada now walks centrifugally from the trunk outward and may attain the leaves. Here a striking change of direction often takes place for the cicada faces about to point toward the base of the leaf, and so again rather toward the trunk. Shedding seems to have some internal drive like parturition in mammals. When the time comes each cicada stops short, may be on the trunk, on the branch or on the leaf, and anchors its claws carefully, to remain as if petrified. This may happen prematurely down in the grass, but this is not the ideal place sought for so eagerly. On the earth the cicada marched toward the tree trunk so intently there seemed dire need for it to overcome all obstacles. If it encountered a man lying down, it surmounted him and walked on over him to the tree, but if the man were standing up beneath the tree the cicada might climb up him and even transform fastened to his clothing, without reaching the tree. Again when a fence was put up close to the tree trunk to keep the cicadas off, this was but of little avail as the cicadas climbed the fence and though some did transform on it, others went to the tree. There was found, however, a sure means of keeping the cicadas from the trunk of the tree, namely by surrounding the trunk with sheet tin, or some other smooth surface, that the cicadas could not attach their claws to. Despite the strength of the urge to reach the tree many are overcome on the way by the other urge, that to climb. Thus in 1919 cicadas walking 60 feet toward a tall tree were arrested near it by chickenwire net and tall orchard grass stalks and climbing up transformed without ever touching a tree. In the same spot in 1936 the cicadas did not reach the tree but finding the tall grass-stalks managed to climb up and having accomplished this very difficult stunt found themselves, like the boy upon the masthead on "old ironsides," unable to come down. Yet in this most unusual condition they managed to anchor themselves and actually transformed waving on the slender stalks. This substitution of grass for tree does not mean that the cicada did not see the tree but only that, not being an instrument of only one string, the urge to climb came to expression out of its usual time—that following the reaching of the tree.

As we have seen the cicada uses its eyes to find the tree but after that climbing

and subsequent transformation may be carried through without use of the eyes, for when we covered the eyes of cicada nymphs walking toward the tree with black asphalt they were lost and did not find the tree, but when we put them to the base of the tree they took hold, climbed up and out on branches and in the night transformed from blinded nymphs to flying adults, leaving behind as witness their old brown shells which were translucent except for the two blackened horny spectacles that had kept the light out of the eyes of the marching nymph.

Such brown cast-off shells remain everywhere in cicada years as witness of the transformations that took place and when found months afterwards still fixed, in sheltered places, are well worth study as they show not only the exact form and size of the nymph that crawled, but also when moistened reveal something of the marvels of the escape of the winged creature from its nymph case. For within the brown husk we see the long white threads that were the linings of the breathing tubes, also part of the lining of the intestine then cast off, also the large tendons to which muscles were attached, both in the chest and in the claws; as in the shell of a common crab.

The transformation itself is but the last of the half dozen sheddings the creature has experienced in its long life but as it launches the stumbling crawler into the air as a creature of strong and beautiful wings it is an astonishing transformation. As the cicada stands anchored, a crack begins to open up on the back near the head and reveals the white "undies" the creature has been wearing. In its inner white suit the creature swells and bulges more and more out of its old brown suit. Oozing as it were out of the rent, the animal shows more and more of its soft whiteness. There are from the first, however, two striking squarish black areas on the back—later after longer exposure to the air much of the white will turn black—but these two areas are black to begin with. Fancifully they may be compared to the large "false eyes" seen upon some insects and suggesting a possible use as frightening away enemies; however, a real explanation for the early blackening of these two spots is yet to be found. Before long the animal manages to pull its head out of the old shell; at least the normal cicada does so, but some poor wretches never accomplish this and perish. The head bears the large colored eyes wide apart. Against the light we note that the hind end of the old brown shell is empty and we infer that some of the pressure that forces the animal out through the back of its old coat arises from the creeping motions of the tail end drawing itself away more and more from its encasement. After the head the legs pull out and the body stands out so that only the tail end remains sticking within the old shell, holding on, we surmise, to the large tendons in the thorax or chest, that will remain inside the cast-off shell. All the while the animal seems dead and as if forced out of its shell much as a crab swells out of its shell to become a soft crab. A strange thing is that the cicada stands upright in its old shell as if an esquimo were to stand up in a kayak, for the tail end has moved to the middle of the shell and most of the body sticks out into space. In fact we fear that the creature surely will fall since everything is upside down and nothing but the grip of the tail end prevents dropping to the ground. Thus standing bolt upright, we see them all about, perfectly still, with something of the gruesome suggestion of little shrouded corpses standing up, each in the middle of its coffin.

But watch! Each suddenly comes to life, bends its back strongly forward and with the new soft feet seizes hold of the old shell and moving forward along it pulls out its tail-end and is at last quite outside the old shell. The cicada once

out, walks forward from its old shell onto the tree and we now see an advantage in the position taken on leaves with the head toward the stem, as now the creature can walk straight ahead and not have to reverse, with danger of falling off, as would be the case if it had not cleverly turned about-face on the leaf before anchoring itself.

On the tree the new birth must remain quietly till its skin changes to black, brown and yellow in place of white and till it has pumped its wing pads full of air and let them dry. Then in the morning flight comes easy. Henceforth the cicadas know the ground no more, unless by accident thrown down, and then they revert to the old habit and progress along the ground to climb some tree from which to take off again in the air.

When the wings were still soft and there was no power to fly the cicadas when put upon the grass crawled along to the tree again and went up it as they had done before transforming. Many there are that fail to expand their wings properly and such cripples clutter the earth and exhaust themselves walking and climbing and falling.

LIFE ON THE TREE

While the tree serves well as the place for the transformation into the winged state this is by no means the final part it plays in the drama of cicada life. It serves also as mating place and as savings bank, into which are deposited the eggs, that alone secure the continuance of the cicada tribe after all these adults have passed away. Once endowed with wings the cicada is strong and active but does not choose to fly far from its home acres but remains within a few hundred feet of the region it long lived in and at this season there are few gales to drive it far afield.

Actually as it flits from branch to branch, day after day, the cicada traverses much space, but it does not migrate to new regions as may the true locust. We observe them fly far out from branches and then curving return to the same or nearby trees. At first they seldom alight upon buildings, but may circle about a chimney without alighting and then seek some tree where they generally alight upon the tips of branches and leaves.

Flitting about they have every appearance of seeing the trees they fly to and when we toss one up into the air it rises high and soon lights upon some tree as if selected from a distance.

Here the eyes are made use of as in crawling toward a tree.

Thus when we paint both eyes with asphalt and throw the cicada into the air it flies rather weakly and falls to earth, or else, may be chances to strike against the observer and then seizes hold, though blind. When all the little eyes on top of the cicada's head were blackened their flight seemed to be quite normal.

A very interesting sight, recalling the circling of pigeons, was furnished whenever we painted one of the large eyes, right or left, and tossed the cicada into the air. Then the insect rose in circles, first smaller then larger, that is in an increasing spiral. Remarkably soon, after sometimes but two, though usually five or six circles, the cicada recovered power to fly straight and flew to a tree, as if seeing it. In these circling flights the insect turned toward the side that was blinded. When the eye was not well covered flight was but modified in part. However, when the front half or the hind half of both eyes was covered, there was no flying in vertical circles and there was good direct flight to the tree.

Care was taken not to paint the feelers as when this is done the insect tries to clean them, as is habitual, with its front feet and when the feelers were stuck to the front of the face the insect still continued to make passes alternately with right and left foot, though not finding the feeler in its accustomed place. However, even when the feelers were thus plastered down to the face, the cicada did fly well and find trees as if normal.

The best exhibitions of flying were in the warm sunshine. As the cool of eve-

ning comes on cicadas fly less and when then taken and tossed into the air they do not rise but soon come to earth. Bright light and warmth favors, and darkness and cool retards, active flight. It is chiefly in the hot sunshine that the cicada is an active flyer, at night it returns to the crawling phase.

Much time is spent actively searching about, crawling upon the branches and leaves. On the tree they are devoted to four things; getting a drink, finding a mate, making a noise, or else laying eggs.

All this lasts but a few weeks then the flying ceases, many fall to the ground, are weak and die, even if not attacked by the strange fungus that fills the bodies of so many. In this region the duration of flying life for the cicada clan was, roughly, in 1919 the three weeks from May 28 to June 20 and in 1936 the four weeks from May 21 to June 23, but it was not determined just how long one individual remains capable of flying. The first mentioned use of the tree, that of supplying food or drink is the least important and has often been overlooked or regarded as nonexistent. However, this year there was abundant evidence that the cicadas did drink juice from trees; both males and females gained something from apple, pear, Washington thorn, rose of Sharon, and apparently basswood, tulip and pecan. At times, especially afternoons, we see dozens of cicadas standing on the bark of a small tree with heads all upward and may be in rows, seeming asleep but rather quickly breaking away when disturbed. Cautiously raising one from its crouching position with elbows down and beak shoved against the bark, we note that as the beak is pulled away the dark inner tools come out from far within through a definite hole in the bark. Also round about and below this hole the bark may be wet with juice that is sweet and attracts passing ants to lap it up. The amount of juice thus withdrawn is not known but in hot dry weather the active cicadas do not dry up but on the contrary they are full and have to spare, so that under a tree crowded with cicadas there is a little shower of droplets they give off and when they are disturbed they cast off liquid in jerks as if for protection; like to the protective discharges of some of their relatives, bugs that give out honey-dew to the benefit of ants and other insects.

SOUNDS AND MATING

The tree serves also for meeting, mating, song and egg-laying; in this first and last reunion of all the cicada clan.

When the cicadas have taken on wings it is evident that *about* every other one is a male, as easily recognized by the shape of the hind-body with its large hooks or claspers, and by the fact that only on the male do we find the organ of sound as two large drum-heads under the middle of the body. The female on the other hand lacks any sound organ and bears upon the hind body, beneath, the very evident boring apparatus for the piercing of wood and the laying of eggs.

When first flying there is no noise for several days, it may be four or five, and then we hear the distinctive sounds of these seventeen year "locusts," not to be confounded with anything else, difficult to describe or to recall in detail. When hundreds sing together the sound is phenomenal: some compare it to the noise of a fire engine siren, far away; or it may be likened to the distant rumbling noise of a freight train to which some singing of wheels is added. Heard early in the morning when robins are singing the cicada chorus suggests a mob of angry crows, yet it is not so harsh and has something musical in it, like the ringing of multitudes of sleigh bells all together. It is primal, and

quite unlike the buzzing and rasping of other insects, suggesting rather some wind instrument or even the vocal efforts of wolf or owl. The peculiarities of the sound are connected with the fact that it is not made by scraping hard surfaces together as are the late summer sounds we hear from crickets, ivory crickets, cone heads and katydids, but arises from a stiff membrane pulled out of place by powerful muscles and let spring back into place. The sound is reinforced by large air spaces and membranes that act as sounding boards.

The males give forth their normal cry when upon a tree or some object and not when flying. As the sound issues the hind body is held up and we see the air spaces above the drums, but then the body falls and the sound ends with a fall in the note as the apparatus is closed up and no longer worked. The sounds last three to four seconds and are followed by a pause. To us the sound seems like e-e-e- or, we-we-we- or, better more of a growl, as ur-ur-ur- continued for about three seconds and then dropping abruptly at the end as ow, or wow, or row, or yow.

The characteristic abrupt drop at the end was expressed in the common belief that the insect said "Pha-r-r—aoh," being of course one of the locusts that threatened Pharaoh, long since. If this is the cicadas usual chant it has other sounds to make when frightened by seizure or when sitting quietly and dreamily whispering to itself.

As in other insects the summation of sounds of individuals makes indescribable complex totals when all the multitude is active at once. Often the chorus arises and falls but with no steady rhythm. When heavy rain falls all are silent and in the night time sound arises only at intervals in very warm weather. In the daytime it begins before the birds sing and lasts on to the cool of evening. In the early dawn it may start far away and approach as others take up the refrain, spreading along like the pattering of multitudinous drops as the shower spreads over the wooded mountain. Be it noted, however, that there is another song different from the above; in fact there are two songs and two kinds of seventeen year cicadas, associated together hereabouts, two species known to the entomologist as *Tibicina septendecim* (Linn.) and *Tibicina cassinii* (Fisher). The sounds made by the latter, the smaller, are more harsh and rasping, yet the organ of sound is of the same nature as in the larger, lighter-colored species.

The tune of the little black fellow is a few chirps and then a buzzing for three to four seconds: that is it seems to say, zig—zig——z-z-z-z-. Thus singing we noted that many keep step with one another at times so that there was a chorus of great volume swelling for about four seconds and then followed by silence for about three seconds. This takes place in a sort of dance when the small ones congregate together on tips of twigs, sing together and then fly off together in silence—a short distance, to return again: and so on. In this dance they are silent on the wing but sing as they sit, and very many fly together and remain sitting together the same periods.

While both these two kinds of cicadas occur mixed together on trees and bushes, we often found more of the smaller sort congregating upon smaller trees and more of the larger sort upon the tops of larger trees, where however they could not be well seen. The waves of sound in the treetops, starting as early as three-thirty in the morning, were chiefly the utterances of the larger form, while the chorus singing in small trees in the heat of afternoon was the work of the small forms.

To connect the terrific amount of noise with the mating habits of these insects is not as easy as one might expect. In the first place it is difficult to find cicadas in the right phase, or stage, of maturity. To be sure, they are all about seventeen

years of age but they did not actually all emerge the same day but through a period of weeks, and the start some got may be kept by them: at least some sing before others do, some pair sooner than others, some lay eggs before others and some die sooner. They are all not doing exactly the same thing on any given day. This increases the difficulties of following the life of any one individual that may be in amongst others that are doing various things in their allotted cycle. Very many are singing and few mating. In general singing precedes mating; so we search for a sequence, but in vain.

In the cricket it is proven that the female walks toward the singing male till they meet and mate and we look for something of this sort in cicadas, but we are disappointed. When many males were kept in separate cages over twigs of trees there was no congregation of the other sex as if attracted. In the aerial dance about the twig ends, do the males somehow attract the females there and do the males flitting here and there search for the females? Mating takes place on the branches and lasts long so we easily see males and females that have met, always large sort with large and small sort with small, but when we watch males and females on the branches, though near together we see no indications that they are aware of one another. A silent male may some half-hour later be found pairing with the near-by female, or in other cases have flown away.

The sounds are heard in June so that every seventeen years this comes to us a noisy cicada month. Some begin before the crowd, and some linger on after the crowd is silent: while for a few days we may hear none at all, yet some last songster later surprises us. By a strange coincidence the last singer recorded in 1919 was heard June 28 and again in 1936, after a few days of silence, the last singer was heard on June 28!

We are told that as yet no organ of hearing has been discovered in the female cicada and the sounds we hear may play but small part in bringing the sexes together in pairs, as apposed to bringing them together in droves. The actions of males toward other males and females full of fungus suggests that contact-stimuli may be potent in actual mating. Awaiting better evidence for associating the great cicada chorus with mating we are thrown back upon other attempted explanations for this monstrous volume of sound. Fabre concluded that his French cicadas sung for "the joy of life." Meyers thinks that the community song serves a useful purpose for the species, though it has but a secondary value as aid toward mating. He points out that while the cicadas possess powerful wings and muscles yet they do not migrate like locusts but remain pretty much in the same spot, generation after generation, and the terrible racket the males keep up in home trees may help to keep the clan together and prevent stragglers from wandering away.

And we will add that the holding together of the clan in one small region may have somewhat of the same advantage as accompanies long life underground. That is, coming forth after their enemies have forgotten them, though they may be decimated by all the enemies at hand, yet more survive from the whole flock, than if they came forth every year, or if they came forth widely scattered amongst widespread enemies. The enemies do not concentrate in these spots of emergence and those there become satiated before the cicada army is annihilated.

THE EGG IS LAID

As the male is specialized to spend much muscular labor in singing (which we hope is some use to the race) so the female is specialized to spend much muscular labor in depositing eggs, of great use to the race. Usually for laying the females select the small branches of trees, or of large bushes, and crawl along the under sides. Only some aberrant cicadas lay eggs in the soft annual growths of such plants as tomatoes and dahlias though down in Mississippi cicadas were credited with laying eggs in blackberries and according to a note in *Insect Life*, 6, 1894, p. 378, those who refused to pick the berries said "Them singin locusses done pizen em with thir aigs."

On the trees the cicadas commonly work upon twigs of about the thickness of a lead pencil and often of last year's growth. When they use smaller twigs this frequently works disaster as the twig breaks off and hangs with dead leaves, or falls to earth so that oaks and many other trees long look as if the twigs had been scorched by fire. But the eggs laid in such small twigs that fall are found dried up and are not successful. On stouter twigs the female stands upside down and with the same sort of firm grip that was employed when anchored for transformation forcefully shoves against the overhead twig, just behind herself, the specialized set of boring tools that penetrate through the bark into the wood, however tough. On the right and on the left she drills, or rasps, or saws, two chambers that meet as a V with one common opening. As the chamber is made on either side it is filled with a number of long slender eggs slid down the drilling apparatus into place to stand close to its fellows, like sardines in a box. As the eggs are long spindles they look something like cigars in a box, but stand at 45 degrees, with what will be the head-end toward the common opening. Having made and filled one pair of chambers the female moves forward a bit and makes a second and a third and so on to finish with often a long series before walking elsewhere to resume laying. Each has several hundred eggs to lay and these are distributed here and there on other twigs. Other females coming by lay also and soon the eggs of various females and of various ages are found in long series of chevrons along the under face of the twigs. It requires strenuous work for the female to penetrate the wood of oak or maple or other trees and the very visible play of the muscles forms a "danse du ventre" that has a very practical value in the cicada life-history. Not only do the powerful tools penetrate the wood and implant the eggs but they so rasp up the fibres that these project out of the common opening of the two chambers as a veritable brush of woody fibres. Long rows of such brushes may be felt along the under sides of twigs, even when it is too dark to see that any cicadas had been there. The eggs laid, the mother soon passes out of life and leaves the eggs to develop by themselves.

THE EGG DEVELOPS AND THE YOUNG GO BACK TO EARTH

Two by two, side by side, with a dozen or so brother or sister eggs in a closed chamber guarded at the exit by a brush of fibers of wood, each egg is well protected and kept from drying by the moisture of passing sap. It will run through its development in the month of July, for as June is song month so is July development month for these insects.

It may be reiterated that the eggs are so placed that young will form within them without further care from the parents, in fact the parents are now all dead and the young will never see them nor did the parents ever see their potential offspring. As being so common and abundant no special study of all the details of cicada making in the egg has been published, but we may take for granted that the general rules followed in other insects hold here also. First the egg looking like a diminutive rice grain has the value of a single cell from the female, and secondly there was added to it the essential part of a cell of the male. From these two parental components are gradually made the thousands of cells that arise and contribute to the making of nerves, muscles, digestive organs and reproductive organs, male or female as the case may be, that are properly assembled to fashion a diminutive model of a cicada of this style.

In some weeks of time such little cicada

is fashioned within the egg shell, unless some accident befalls, as for instance, the intrusion of the egg of some parasitic ichneumon fly that will hatch and destroy the cicada egg, or the encroachment of the wood of the tree itself as it strives to heal over the wounds made by the laying cicada. In fact most of the trees injured by cicadas do grow new wood along the sides of the punctured areas and these side swellings do sometimes entomb the eggs, but generally the young escape before the wound heals over and the tuft of fibers seems a rather good thing for the cicada, as it sticks out and can be overgrown only with difficulty and long lapse of time.

When the young is ripe for hatching it must first break through its tough egg shell and then travel a bit to get to the exit, before it can walk on the outside of the under face of the twig. To see something of all this we take twigs from different trees and place them in milk bottles of water to keep the stems from drying out. Then we find that the hatching, like all other events of the crowd, takes place not all at once but strung out over some weeks time on different twigs and often upon one twig where several had laid. When hatching has recently taken place we note a peculiar addition to the region of the brush of wood-fibres that guards the entrance to each pair of egg chambers, that is, a tuft of faint white threads, as if some fungus. Under the lens this proves to be more like a dozen or so minute cups of glass upon long twisted white stems, in fact they rather suggest champagne glasses, with long crooked stems stuck together and without bases, fastened to the fibre brush at the exit; empty glasses left behind after the celebration of the escape of the young! Then digging into the wood we find the clear but tough leathery egg shells standing just as they were laid but now empty and each split open along its end toward the exit. Inferentially the young did move each its own length to get out of the long egg shell and then move some little distance more, to get to the exit and vanish, after leaving the empty "champagne glass." To find out how the young escape we cut open twigs that have not yet displayed the little glasses on threads and in various twigs find embryos not yet escaped and in various steps of escape.

Within its shell each embryo is so made that it is not free against the shell, but is enveloped in a sort of caul, or clear membrane, fitting over each limb all in one suit. The movements we see it make are not walking but creeping movements. The body is long and worm-like and the first movements seen are those of a creeping worm rather than of a creature that will do so much walking and finally fly. As the young nymph leaves its shell it is not free, but still within this inner suit. In this we see it slowly advance toward the exit of its chamber. We see waves of contraction from the tail end forward along the rings of the worm-like creature. Thus the tail is shortened and the head pushed forward, little by little, ring following after ring, till the entire animal is farther and farther from the egg shell. These crawlers from the egg shell will crawl even on glass, like maggots, to which humble creatures they have resemblance in their locomotion.

We assume that the creeping-like movements forced the narrow head of the creature against the egg shell till it ruptured and let the inmate, still in its inner casement, crawl slowly forth, like an inner tube bulging from a casing. Watching the nymph after it leaves the egg we see it shove its shovel-like head along between the wood and the overarching fibres and note that besides the worm-movements there are also some slight motions of the legs. But these are not yet free, but as it were in bags and can move through but a short arc, being bent down toward the body and never as yet raised far from the position they were built in along the under side of the body, like unto the blades of a pen knife when but slightly opened. Likely these confined legs serve to hold what is gained by creeping and prevent retrograde motion. Thus slowly creeping the nymph finally goes a few lengths and attains the exit opening along with some of its fellows and pushes out above the wood fibres. Its continued worm-like motions thrust its body out into the air as if it might fall from the twig. Hanging thus it makes violent bending of the body, bending down its head and rearing up its tail, swaying violently.

And lo! the case that impeded its motions breaks open at the back of the head, as will other nymph skins in later life as they shed and grow till the final transformation shedding. As the animal withdraws its tail end from this first larval skin this collapses and shrivels and as a shrunken tube looks like a mere crooked thread. In truth, the white strings, left sticking to the wood fibres at the exit are but the accumulating cast-off first larval skins of the young that hatched and crept to the common exit. Each string is hollow throughout as it was the covering of the long worm-shaped larva and from it stick out remnants of the tubular covers of the limbs, that could not be moved well till these were cast off. The head

part of the larval case remains open as the glassy cup and from this there sticks out, very often, a minute thread like a straw from a goblet, and this is hollow and as it comes up from the tail end of the larval skin we regard it as the cast off lining of the intestine comparable to what we find within the old husk the last nymph leaves on the tree when ready to expand its wings.

Greater magnification of these cast-off larval skins of the first stage shows that though they appear to be but crooked strings they present on the outsides of the rings that compose them many crosswise rows of fine projections, like the teeth of a rasp, and so pointed toward the tail end that they should aid the forward motion of the crawling creature in its first, but very important, journey in the world, and enable it to crawl even upon glass. Thus is the infant provided with a good anti-skid set of tires, for its first brief but difficult trip.

Returning again to the actual casting off of this glassy skin, we saw that when the head stuck out the feelers that had been built bent down along the face, sprang up and were long and well formed. Then the legs came out also into the air, requiring work as each is within a skimpy covering which tends to be pulled inside out. When once free the limbs are used, bent into place and stretched forth to anchor to any roughness, so that the animal walks out of its case and away from the exit. Though the limbs move with some trembling and tottering the infant does not pass from crawling through a stage of falling but walks as knowing how and coördinates the motions of its six legs.

The cast-off clothing is sticky and adheres to others and to the wood fibres till some puff of wind carries all away. To repeat, the creature made within the egg crawls out of its egg and crawls a bit of a journey to the exit, encased in swaddling clothes that hamper free motion, like tight skirts. Here it meets the light and violently bursts out of its temporary larval suit. As Fabre points out, free legs and walking would be difficult in the confined chamber and its encroaching fibres, while the insinuating crawling is better to bring the creature safely past the obstacles into the open where it can walk free with its wide spread legs.

In trying to picture the little one that takes its first steps we may think of it as like the old nymph, but also very much smaller, slenderized, pale and long drawn out, suggesting, perhaps, with its great claws, the wraith of some Lilliput lobster. The creature is all white except some small points of yellow-brown and the dark of the small eyes. Even within the egg and inside its first larval skin we saw the dark-red black of the eyes most clearly, eyes that now are (though compound) very simple, as compared with what they will gradually become as years go by, though their use seems non-existent most of the time. At that time also, within the egg shell, there were yellow-brown spines at the ends of the legs and on the claws and also fine brown bristles or hairs scattered over the body and held down flat till the larval skin was cast off, and then they jumped upright. The head is now rather a wide shovel and blunt and bears already a small sucking tube beneath it. The body still shows worm-like rings and the three of the chest are larger, especially the first that bears the big claws.

These cicada claws are fashioned by growing spines out from the second and the third parts of the leg, counting from the tip, so that the spines form a sort of pair of forceps for picking up objects and also for scratching or picking earth. This leaves the outermost part of the leg of less apparent use and Marlatt discovered in later years it will almost disappear. The animal stands high upon its other four legs and walks ahead like a quadruped but helped along by the pulling of its first heavy claws and their tips.

These active little fellows run restlessly about on the twig, and one was observed to stop as if trying to draw juice from the bark. Indoors they soon fall off and outdoors they cannot be found on the twigs. In this region the period of time through which cicadas are coming forth is about two weeks, that is, in 1919 they were hatching from August 8 to 23 and in 1936 from July 29 to August 14: this year's early beginning may have been due to hot weather. In other words, all the thousands of cicadas in this spot after seventeen years of concealment crowded their emergence into about two weeks of time and their offspring all came out

within about the same half-monthly lapse of time.

We wonder not only at the great stretch of time taken to finish the life cycle of these cicadas, but at the conservatism with which the cicada clan adheres to family traditions.

Excerpts from the diary of a youthful cicada of Baltimore might read "Our parents when children entered this land in the trek of August 8 to 23, 1919, worked hard at mining and the sugar business till 1936, when they migrated with the clan to this green paradise from May 21 to June 6 and here they sang and labored for our good a brief three weeks and then passed on, leaving us snugly cradled in the swaying boughs. Let us then so live that we may follow in their footsteps and celebrate those dates in 1953."

Looking for the young ones is like looking for the needle in the haystack: a few were found under objects upon the ground where they could not dig, but when kept in receptacles the young dropping from the twigs soon conceal themselves, if possible, and in 1919 we inferred that they were light-shy and crawled away from the light.

However, we now find as did Snodgrass then, that the young at hatching are positive to light under indoor conditions.

In a dish they walk strongly toward a window and reverse when the dish is turned about. This is as persistent a trend as is that of the nymph going toward a tree and here also when turned to the right it turns to its left and resumes its way toward the light. However, some few there were that walked away from the light and these seemed shorter and less white, as if older. When a lot of young, hatched less than a day, were put upon a black paper two and a half feet wide and five feet long toward the window, there followed a veritable cicada marathon toward the window. Some few finally strayed off the paper on the sides but most all went directly forward and as fast as they could walk toward the window, in open formation and not in files, each to itself. One soon getting a foot ahead of the others finished the five feet in eight minutes. Many did it in ten, some in twenty and a few had not finished in twenty-five, but these wandered. Three went only three feet and then wandered about. Two went away from the window light and when one of these was put near the window end it started directly away from it, but after going a foot in five minutes it wandered about. Those that finished were left walking in a dish for half an hour and then started over again. Most all the thirteen started direct for the window again though a few first wandered and then went toward the window. One that went away from the window was put near it and still walked from the light. Another was also negative to light. Of the eleven positive some finished in thirteen to twenty minutes but others changed to negative, at times, and wandered about. Seven that finished were tried again but they went off the sides or advanced with reversals and wanderings, except one that finished in twenty minutes, having gone fifteen feet plus the walking in the dish. Apparently it had been striving toward the light for some eight hours at the rate of twenty feet, or so, per hour; this should bring it somewhere.

So much for the performance of the walking cicada indoors. When we dumped a hundred that had been hatched some hours on the grass and earth beneath a tree we saw something more complex. These did not walk off toward the setting sun but scattered widely in different directions over the rough surface. Some fifty are seen wandering over about two inches square of soil amidst grass and soon all are vanished. Some walked a few inches and were lost in the grass, some came upon holes made by their parents and went in, where some climbed down the sides and others fell down—not to return for seventeen years, we assume. Here the young appear to profit by the work of the older generation, if they are thus led more readily to the roots they need. Two larvae were carried off bodily by ants, one of which was smaller than the cicada. But most of the vanished cicadas were still about where they were thrown down, but had managed to squeeze into crevices, or cracks or under lumps in the soil. Though the gait of these walk-

ing infant cicadas is rather tottering, as compared with the native occupants of the grass, yet we found they could actually dig in. One seen within a hole as wide as its outstretched limbs was rather staggering about, yet after a time it emerged and then disappeared again. With pocket lens it was seen to back out bearing in its big claws a particle of earth, then turning to one side thrust the burden from it and shoved it against the side of the little pit. While its motions were vague and weak as compared with those of an expert ant, its methods were those of a born miner. Others, put upon earth under a binocular microscope, were seen to dig in slowly but surely and so to vanish below.

In 1919 the Japanese student Yasushi Ibara stated that these young cicadas attach themselves to the roots of grass, but when we now try to see them do so we fail. Many were kept several days in glass receptacles with grass roots, but though the cicadas continued to scramble about amidst the grass roots we did not succeed in finding any that were attached to the roots or sucking juice from them. If it be the cicada's habit to feed upon grass roots on the way down, cicadas in suburban tracts where both trees and lawn abound would seem to have some advantage over the primitives of the woodlands. We do find some of the most populous assemblages of cicadas upon such tree strewn lawns.

DAMAGE DONE

"Before them there were no such locusts as they, neither after them shall be such,—they did eat every herb of the land and all the fruit of the trees—and there remained not any green thing in the trees, nor in the herbs of the field, through all the land of Egypt." *Exodus* X, 14–15.

Having once connected our seventeen year cicadas with the locusts of Pharaoh's plagues, we expect to find great damage done here, as in the orient. Yet, as a matter of fact, we find little of ill can be laid to the cicada hosts. The government maps show broods of seventeen and thirteen year cicada issuing almost every year from one part or another of the United States but there is no such wide spread continuing devastation as would call for large expenditures in attempted control.

All these broods are in restricted areas, there is no general outpouring over vast areas. In the maps of Marlatt are some thirty broods chiefly over the states to the east of the Mississippi River but with some few to the west, where other kinds of cicadas occur. Some of these broods occupy but a very small part of a state though others, like our present brood X, reach over parts of several states. But of course cicadas are no respecters of state lines and a brood appears over an area that has no boundaries that are understood as causes for limitation. While the thirteen year variety is more prevalent in warmer states they overlap the more northern variety and yet indicate some climatic factor involved in the distribution.

In general, history shows that these cicadas were more abundant in virgin forests and have receded like many wild things with the advance of cultivation. Yet some wooded areas still hold much of their former strength of population, as at Plymouth, Mass. where the brood of 1634, coming down through sixteen generations of seventeen years each, recurred in strength in 1906.

What damage is done is in these mapped areas and in them it is only the wooded parts that are affected, not the large regions of fields and crops. Moreover, not even all wooded areas or regions with trees are occupied by cicadas. When at its height the noise of the cicada is but

very local and one can easily escape it by short journeys in any direction. The regions of sound are scattered here and there amidst the larger regions of silence.

As we motor through Maryland months after the cicadas are gone we can still recognize infected areas by the dead twigs and leaves dangling from forest trees, or encumbering the ground as an added nuisance to the man who tends his lawns.

Were one to designate by red dots such infected areas in a state or county or district there might well result an instructive chart of strangely scattered and discontinuous distribution of these insects. Very large areas that seem fit for cicadas do not exhibit any and we are led to infer that there is no such ready means for cicadas to be distributed all through the land as there is for many a weed; more the pity.

The damage done is then very much a local affair; and it is not the destruction of trees but only their too severe pruning. The tips of the branches are injured, many leaves are killed. But these leaves had already served the tree for a period and the tree may spare them. The greatest loss is the foot or two of terminal twig with its many buds for next year's growth. The cicada prunes off some of this year's growth and so retards the tree. In our little fruit trees and smaller shrubs this may be of great importance, but it is as nothing compared with the damage done by many other kinds of insects that work in silence. What is of import is the fact that the twigs are damaged far below where they break off and far more injuries remain upon the living parts of the tree than are suggested by the shrivelled twigs. Inches, or feet, of the undersides of living twigs may show the scars resulting from the egg laying operations. Though the tree rapidly heals over the scars yet there is here but half a twig, the lower part being mostly dead. These are weak points and in storms, for years to come, the branches are prone to break off where the cicadas injured them. Long before healing over, various fungi, beetles and aphids gain access to the living parts of the tree through these wounds. Scars are recognizable even after the lapse of seventeen years, in some cases. Thus the cicada pruning continues to have results and the tree is hampered more than at first sight seems to be the case.

To be sure only half of the insect horde is guilty of wounding the trees, only the females of the species are to blame, yet the male shares in the guilt of taking sap from the trees. To our puny house plants the attacks of sucking insects, especially when they not only draw out sap but inject saliva, may be most serious, but the sucking of sap from vigorous tree or shrub in the open, whether by bird, aphis or cicada may be a venial sin.

Yet when we see a young pear tree with its bark wet with the sap wasted by twenty sucking cicadas, we wonder if the tree were not better without this hypodermic treatment. What shall we say of the long years of sap sucking done by cicadas on the roots of trees? Such stealing of sap cannot be of benefit to the trees and may be some harm, but evidence appears to be lacking. If the cicadas hold back the growth of trees by taking juice the years they are underground then the tree may grow better the year or two the cicadas are not feeding and are coming forth and it is even possible that careful study of the annual rings of old trees infected through several generations of cicadas might reveal some wave of periodicity approaching seventeen years.

At all events the cicada is not convicted of ill to the plants man most depends on and he need scarcely consider how to exterminate the cicada Let him rather

take steps to conserve broods in forest reservations for the wonderment of future generations, who else might not have so good a link with the forest life as the Indian saw it.

If in any region we desire to curb the injuries inflicted upon plants we like, and upon our jazz-vexed eardrums, emphasis should be laid upon the most vulnerable link in the chain of cicada activities, the period of emergence from the earth. Down below the cicada is safe from attack unless we venture to pour down carbon disulphid, as has been suggested, while up in the trees it would be expensive to reach them with poison spray. However, when the cicadas march along the earth to the tree, in the gloaming, then they are easily captured. And that is the period when the ancients deemed them a delicacy for the table. In fact they are then full of fat and are nutritious and to be compared with soft crabs. Yet we may relegate the eating to pigs, ducks and fowl and all our song birds, as well as squirrels and other cicada enemies. One drawback to this plan is that the common poultry go so early to rest that they miss much of the flow of emerging cicadas. However, bands of smooth material, as tin, about the trunks of trees will keep the cicadas down till they can be gathered for the creatures' breakfasts.

This food value of the cicada hosts may some day be made more use of. Should someone collect them and manufacture them into fish food for the aquariums, then the entrance of our cicadas into the land of the dodo, great auk and passenger pigeon would surely be hastened.

But let us rather endeavor to keep some of them with us as fellow travelers in this our common world of earth and air, mindful that the words of the poet apply not exclusively to the cicada:

"Short thy allotted space of sunny hours
Until thy issue sinks beneath the ground."
Latrobe Weston, 1936

LIST OF LITERATURE

Andrews, E. A. Periodical cicadas in Baltimore, Md. *Popular Science Monthly*, April, 1921.

Fabre, J. H. Souvenirs Entomologiques, V. La Cigale.

Huxley, T. H. Diary of the Voyage of H.M.S. Rattlesnake, 1936. Doubleday, Doran, *New York*.

Marlatt, C. L. Periodical cicadas. *U. S. Dept. Agriculture*, 1907.

Myers, J. G. Insect Singers: a Natural History of the Cicadas, 1929. *London*.

Snodgrass, R. E. The Seventeen-year locust. *Smithsonian Reports*, 1919, pub. 1921.

Van Duzee, E. P. Catalogue of the Hemiptera of America north of Mexico. *Univ. Cal. Pub.*, vol. 2, 1917, 902 pp.

A CRITIQUE OF PLANT SEROLOGY (*Concluded*)

PART III. PHYTOSEROLOGY IN MEDICINE AND GENERAL BIOLOGY. BIBLIOGRAPHY

By K. STARR CHESTER

The Rockefeller Institute for Medical Research, Department of Animal and Plant Pathology, Princeton, New Jersey

VI. CERTAIN MEDICAL ASPECTS OF PLANT SEROLOGY

SEROLOGY of plants pathogenic to animals. The pathogenic yeasts and lower fungi responsible for disease in man and other animals have frequently been the subject of serological investigations. In the limited space of the present paper it is not possible to consider all such investigations, and accordingly the following discussion is designed to afford only an illustrative and suggestive view of this phase of plant serology.

While the degree of immunity resulting from infection by pathogenic fungi is relatively low as compared with that of immunity to the bacteria and viruses, it appears that in some cases a significant acquirement of immunity does follow fungus infection or immunization. As early as 1896, Sanfelice (305, 306) showed that the guinea pig, dog, cat, and rabbit inoculated with attenuated *Saccharomyces neoformans* show a decided resistance to tumor formation caused by virulent strains of the same fungus. Michel in 1917 was able to immunize guinea pigs strongly against *Monilia psilosis* by injections of the killed fungus (224), and similarly *Actinomyces gypsoides* extracts produce an active immunity in the rabbit (252). In cases of *Trichophyton* (56) and *Monilia albicans* (177), however, no general immunity followed the inoculation of dead fungus, although in the former case a decrease in severity of symptoms was noted in the inoculated animals.

The property of conferring passive protection in the serum of animals vaccinated against or recovered from attacks of zoö-pathogenic fungi is apparently rarely met with. For example, Citron (56) has shown that, while precipitating sera may be obtained in rabbits inoculated with *Trichophyton*, these sera have neither protective nor curative value for mice inoculated with *Trichophyton*. Nelson and Henrici (252), however, claim that if rabbits be immunized with an endotoxin from *Actinomyces gypsoides* their sera partially protect guinea pigs against actinomycosis.

In contrast to these relatively weak or negative findings regarding immunity to the zoö-pathogenic fungi *in vivo*, numerous experiments have shown that the sera of animals inoculated with living or dead cultures of virulent or attenuate zoö-pathogenic fungi regularly exhibit demonstrable serological effects on the fungi concerned, *in vitro*.

Although a number of non-pathogenic yeasts had early been shown to yield precipitins of a rather low order of specificity (321–324), the precipitin test has not proven entirely satisfactory in all cases with the pathogenic yeast-like fungi.

Positive results were claimed by Citron in 1905 with a pathogenic *Trichophyton* (56), but the earlier attempts with the precipitin method often failed because of lack of a suitable test antigen (e.g., 224). In 1925 Balls (16) reported successful precipitin tests with pathogenic yeasts by the use of autolyzed yeast as a test antigen, and shortly afterward the development of the use of the water-soluble specific carbohydrate of pneumococcus led to an application of the same technique with pathogenic yeasts, particularly by Kurotchkin and his associates (166, 167, 178) who obtained high-titered precipitin reactions between the sera of inoculated animals or infected humans and purified preparations of the water-soluble specific carbohydrates of *Monilia tropicalis*, *Trichophyton violaceus*, *T. cerebriforme*, and *Saccharomyces* species. This work has been continued by Kesten and Mott (in 168a). Lamb and Lamb (168a), by the use of a precipitin absorption test, obtained clear cut results separating the species of *Monilia* tested into three well defined groups. Fermentation tests confirmed these serological results.

Agglutinins for non-pathogenic yeasts were observed as early as 1901 by Bissérié (30) and Schütze (321) in the serum of inoculated rabbits. In 1917 Michel found that in severe cases of sprue the *Monilia* causing the disease is agglutinated by the sera of infected patients (224). Similarly, fungus agglutinins have been shown to occur in the serum of rabbits inoculated with the pathogenic *Aspergillus fumigatoides* (307), *Monilia psilosis* (126), other pathogenic *Monilias* (207), *Saccharomyces neoformans* (192), and a strain of yeast inducing sore throat (270), as well as in the serum of a patient dying from infection with *Monilia pinoyi* (270). They were not found in normal human sera or in the sera of cancerous humans (37). While the titers of such agglutinins are not usually high, in some cases positive reactions have been reported with sera diluted 1:5120 (207). It seems evident from the work of Defalle (64) and others that it is the wall substance of the yeast cell and not the protoplast which acts as antigen.

Positive complement fixation reactions have been reported with the sera of laboratory animals inoculated with pathogenic species of *Monilia* (224, 167, 207, 178) and *Saccharomyces* (270, 306, 178), and with the sera of cases naturally infected with *Actinomyces* (252) and *Monilia* species (224, 83, 167). They were not obtained with normal or cancerous human sera (37) nor with sera of unprotected laboratory animals which subsequently died of yeast infection (306). The water-soluble specific carbohydrates of *Monilia* and *Saccharomyces* likewise give complement fixation reactions with immune sera, showing titers even as high as 1:25,000,000 (167, 178). On the whole, the complement fixation test seems the most satisfactory of all procedures yet used in the serological study of zoö-pathogenic fungi. Killed fungus extracts, fungus culture filtrates, and specific carbohydrate fractions have all been used with success as test antigens.

Certain other serological reactions have also been sought in the study of zoöpathogenic fungi. It seems evident from the works of Skchiwan (329), Citron (56), and Peckham (270) that the inoculation of pathogenic species of *Trichophyton* and *Saccharomyces* is quickly followed by phagocytosis of the fungus *in vivo*. The opsonic index shows an increase before either the precipitin or complement fixation reactions appear. In intraperitoneal inoculations of *Saccharomyces subcutaneous tumefaciens* into the rabbit the yeast responds by the production of a thick, resistant wall and is not killed; on the

other hand, intravenous inoculations result in the rapid destruction of the yeast. No lysis of peritoneally inoculated yeasts has been observed in the cases of *Trichophyton* and *Saccharomyces* species, and the serum of inoculated animals fails to exert any lethal effect on the growth of pathogenic species of *Saccharomyces* (193). Davidson, Gregory, and Birt (63) have described a diagnostic test for dermatomycotic fungi, the "trichophytin test." The "trichophytin" is a protein extract of *Trichophyton gypseum*. Of this .1 cc. is inoculated into the skin of the arm and readings are made after 24 and 48 hours. The test is claimed to be diagnostic of suppurative ringworm, since 15 definite cases gave positive tests, while 55 patients with other types of dermatomycosis all gave negative or very weakly positive tests. The serological mechanism is anaphylactic, analogous to the tuberculin test of cattle or to local skin tests in diagnosis of hay fever. Axamit (11) and Nakayama (247) have claimed that pathogenic fungi (a dermatomycotic Torula-like yeast and an *Actinomyces*, respectively) are anaphylactogenic. The reactions obtained were highly atypical for anaphylaxis, however, since if two doses of the fungus were given at 5–7 day intervals death ensued, while if the interval was three weeks (the customary interval for anaphylaxis) there was no reaction. Since the weight curves showed loss in weight during the first week after inoculation, which was subsequently recovered, it is probable that in this case the reactions observed were not anaphylactic but rather due to the cumulative effect of two sublethal doses of a toxin present in the inoculum. Rosenau and Anderson, however, have reported reliable anaphylaxis tests with yeast (297).

A question of particular interest in the study of the serology of the zoö-pathogenic fungi regards the specificity of the reactions obtained. On the whole, it may be said that there is little or no species-specificity apparent in the reactions noted above, and that even on a broader scale it is rather difficult to distinguish the pathogenic yeasts and yeast-like fungi with success. Thus the various species of *Trichophyton* have been shown to be very close to one another according to the precipitin test (56, 166), and the *Monilias* often cannot be separated from one another by the agglutination, complement fixation, or precipitin tests (126, 207, 178). The yeasts of sprue and other blastomycoses have been shown to be very closely related serologically (126). It has been possible to demonstrate a serological difference between the pathogenic and non-pathogenic yeasts, on the other hand (207), and between the non-acid-fast, pathogenic *Actinomyces bovis* and *A. Madurae*, and other, acid-fast, non-pathogenic *Actinomyces* species (252). Balls (16) has claimed an excellent differentiation of yeast sub-species by the precipitin test, but this finding has not been confirmed by other workers. A curious case of heterogenetic specificity has been observed in using the water-soluble specific carbohydrates of yeast in precipitin testing, where Sugg and Neill (344) have shown that anti-yeast serum not only precipitates in the presence of the carbohydrate of pneumococcus Type II, but that it protects mice against these pneumococci, in spite of the very wide systemic separation of the yeasts and the pneumococci. This phenomenon is apparently to be explained in terms of the occurrence of a common, semi-antigenic, non-proteinaceous substance in the capsules of these very distinct organisms.

Hay fever, asthma bronchiale, urticaria, satinwood dermatitis. One of the most outstanding links between medicine and phytoserology concerns hay fever, asthma

bronchiale, and urticaria, all known to be due to anaphylactic reactions in man toward the proteins of many species of plants. The modern conceptions of the etiology of hay fever date back to the studies of Dunbar in the first decade of the present century (68, 69). Dunbar was able to reproduce the clinical picture of hay fever in susceptible patients by the administration of dried pollens of the *Gramineae* and of *Convallaria*. The reactive constituent of the pollen was found to be insoluble in alcohol, ether, and alcohol-ether, non-carbohydrate, highly sensitive to heat and to phenol, precipitable by ammonium sulfate and recoverable from such precipitate, and hence presumably protein in nature. Immunized animals yielded sera which neutralized the toxin efficiently. Dunbar further showed that precipitin and complement fixation reactions are demonstrable between the pollen extracts and the serum of hay fever patients, but not with the serum of normal individuals. Susceptibility may be passively transferred.

These findings of Dunbar have been repeatedly confirmed until the anaphylactic nature of hay fever and asthma are today accepted as proven facts. As practical applications of these findings may be cited the well-known skin treatments for the identification of the particular plant responsible for the condition in a given patient and the efficacy of the serum treatment once the sensitizing species of plant is known (57). Therapeutic treatment is successful in about 75 per cent of treated cases (186a).

In 1910 Wechselmann (360) described an erysipelas-like skin reaction in workers with the satinwood (*Fagara flava* = *Xanthoxylon cribrosum* of the Rutaceae) which he attributed to anaphylactic sensitization, since in non-sensitized workers an application of the wood caused only a minimal burning, while sensitized workmen showed a severe dermatitis a few hours after the wood powder was rubbed into the skin.

Many other plant substances are known to be responsible for allergic reactions naturally occurring in man. These include dried seaweed (*Zostera*), kapok, and jute used as stuffing materials, all grasses, flax seed, ipecacuanha, *Lycopodium*, violet root, *Camellia*, boxwood, rose, cocoa, teak, numerous fungi, coffee and tea, etc. Extensive data concerning these substances, as well as those of animal origin, together with their chemistry and biology, are given in Maass' collection of tables on allergy (186a).

Rhus dermatitis. The serology of the toxic element of *Rhus* and the therapeutic use of *Rhus* extracts in treatment of ivy poisoning have been discussed previously (page 188).

Determination of cause of death when due to plant toxins. The phytotoxalbumins discussed in a previous section not infrequently are responsible for accidental death in livestock, since a number of common weeds contain such toxins, and occasionally cases occur in which human poisoning is attributed to such plant toxins. It would, therefore, be of considerable value if it were possible to prove, in suspected cases, the cause of death.

In 1902 Ottolenghi (267) showed that ingested egg albumin may be detected serologically in the contents of the digestive tract. Schern in 1910 (314), on the basis of such findings, attempted to demonstrate serologically the presence of ricin in the stomach contents of poisoned stock, but unsuccessfully. The following year, however, Müller (243) contributed a technique which detects ricin in the stomach and small intestine after death due to this poison, although the protein had been so much broken down or absorbed by the time it reached the large intestine that it was no longer serologically recognizable. Hiki (125) has added

the instructive observation that plant proteins which are ingested retain their ability to react serologically even after passing into the blood, but that this serological reactivity is lost once the blood passes through the liver by way of the hepatic portal system. It would, therefore, seem evident that under favorable circumstances the diagnosis of death due to poisoning with plant toxins is possible by serological methods and the specificity of the reactions obtained (cf. Part II) would indicate the reliability of the results obtained.

VII. APPLICATION OF PHYTOSEROLOGY IN THE STUDY OF CERTAIN BASIC BIOLOGICAL PROBLEMS

Movement of proteins in plants. The possibility of the specific detection of plant proteins by serological methods opens a new approach to the study of protein metabolism in the living plant, and indeed the difficulties involved in the detection of proteins are such that it is doubtful whether any other approach yet devised could afford similar aid. Moritz in Kiel is chiefly responsible for the little work which has as yet been done in this field. In 1932 (237) he raised the question of whether plant proteins can migrate in the plant sufficiently to permit an immunological sensitization *in the plant* comparable to that which obtains in an immunized animal. It had previously been claimed by Kraus, Portheim, and Yamanouchi (159) that animal antibodies can penetrate the roots of uninjured bean plants. Moritz and vom Berg extended this work, watering *Vicia* plants with ovalbumin solutions and later testing the aerial parts of the plants for the presence of ovalbumin by means of the Schultz-Dale anaphylactic technique. The encouraging preliminary results of this first work were extended and confirmed in a later study (237) and it was shown that the penetration of ovalbumin into the plant and its passage up to the leaves may be demonstrated either by sensitizing the guinea pig with such leaf material and testing against pure ovalbumin or reciprocally by sensitizing the pig against pure ovalbumin and then testing against the leaves of ovalbumin-fed plants. While these results are contrary to a general opinion that substances of such large molecular size cannot freely pass through the living plant, Moritz and vom Berg's work gives every evidence of having been carefully planned and executed, and should be subjected to further investigation because of its importance in an interpretation of such biological problems as that of the physiological basis for immunological sensitization in the plant, and the debated question of the nutritional relationships between the members of symbiotic partnerships, in particular of the mycorrhizal symbioses.

In connection with the serological approach to the study of the movement of proteins in the living plant should be mentioned the work of Matsumoto and Somazawa (204, 205) in demonstrating the movement of tobacco mosaic virus in the plant by means of the precipitin test. By the use of these tests, the Japanese workers were able to follow the virus in its occupation of the tissues of the inoculated host, and to show that the advance of virus as indicated by the precipitin test is correlated with the advance of symptoms due to the virus. They have recently described a micro-method for facilitating this work (201c). Gratia (110) made the interesting observation that, while extracts of the pericarps of mosaic tobacco plants are reactive with tobacco mosaic serum, extracts of the seeds of the same plants are not, in accordance with the fact that tobacco mosaic is not seed-

transmissible. With tobacco mosaic virus it so happens that there are other methods for virus detection more sensitive than the precipitin test, and accordingly this particular case might be better attacked by the use of the local lesion method of Holmes; however, with other viruses in which convenient and relatively accurate infection methods of detecting virus are not available, the serological tests might be used to greater advantage in the study of the movement of virus in the inoculated host.

Investigation of hybrids. Another application of serological methods in fundamental botany is in the investigation of the constitution of hybrids. In 1914 Zade (385) first attempted such a study, and by means of the precipitin test he was able to show that, while *Trifolium pratense* and *T. repens* are related but serologically distinct, their hybrid, *T. hybridum*, reacts so strongly with both as to demonstrate clearly its hybrid nature. Furthermore, known mutants were shown to be serologically indistinguishable from their parent forms.

Moritz and vom Berg have made an extensive contribution in this field in recent years (232, 236–239). In a *Berberis* hybridization it was possible by means of the Schultz-Dale method to detect proteins in the hybrid peculiar to each parent.

Among the grains, in several hybridizations of *Triticum*, *Secale*, and *Aegilops* species, the hybrids were likewise shown to be serologically intermediate between the parents. In a *Triticum-Secale* cross, for example, *Triticum* partially saturated an anti-*Secale* system, and *Secale* partially saturated an anti-*Triticum* system, while the hybrid saturated both but not those of other species of *Triticum*. In a hybrid between *Aegilops* and *Triticum* the hybrid also fully saturated each parent, although the parents were serologically distinct. Finally, in the disputed hybrid *Vicia Leganyi* ("*Lens esculenta* x *Vicia sativa*"), the protein complex of the hybrid (represented as $a + b + d$) was shown to be intermediate between the protein complexes of the parents ($a + b + c$ and $b + d$, respectively).

The protein constitutions of the hybrids are hence found serologically to represent combinations of all or part of the proteins of the parents without the occurrence of specifically new proteins as a result of hybridization (238).

It is thus evident that in the field of genetics phytoserology may contribute instructive data, affording evidence of the genetic distribution of the specific protein, the chemical basis of life and of the secondary manifestations regularly used as criteria in genetical studies.

Contributions to the plant virus problems. The work of Matsumoto and Somazawa in following serologically the movement of virus in an inoculated plant (204, 205) has already been mentioned in another connection (p. 298). Serology has also given indications of affording help in a number of other ways in the problems of virus research. It has been pointed out (pp. 179–181) that instructive aid may be obtained by means of the precipitin, complement fixation, and neutralization reactions in identifying and in determining the systematic relationships of plant viruses.

A third contribution of serology to plant virus research is in the use of serological techniques in the quantitative determination of the amount of virus present in a given sample extract, a line of work developed in particular by Beale with reference to tobacco mosaic virus (282, 283). In Beale's experience, as in the writer's (51), it is possible under some conditions to arrive at a fairly accurate estimation of the relative amounts of virus in two comparable samples by means of the precipitin test, and the development of serology in this connection gives promise of affording useful evidence in the cases

of some viruses which have not as yet yielded to any other quantitative method.

Gratia and Manil (111) have made the valuable suggestion that the neutralization reaction might be used in the purification of virus mixtures. The most frequent and troublesome contaminants of virus materials are the highly resistant and infective viruses, such as tobacco mosaic and the latent virus of potato. Using customary techniques these can be removed from mixtures with less stable viruses only with great difficulty. Yet it is just these frequent offenders which are most highly antigenic and it seems reasonable to expect that the treatment of extracts of two mixed viruses with serum antagonistic to one of the components may yield pure inoculum for the other component. Indeed, recent preliminary experiments of the writer have shown that the serological approach affords a practical solution of this problem.

The specificity of the plant virus seric reactions (50, 281), and the fact that the earlier experiments showed a close correlation between virus infectivity and seric activity (51) led to an assumption that in these reactions it is the viruses themselves which are the antigens concerned. Very recently, however, it has been shown that preparations of the viruses of tobacco mosaic (332b) and latent potato mosaic (20a, 20b) may be treated with formaldehyde or other agents in such a way as to eliminate their infectivity without affecting their seric reactions. Two interpretations present themselves: (1) that the seric reactions are due to virus which is so affected by certain chemical agents that it loses its infective power without losing its specific antigenic character, or (2) that the reactions are due to a specific by-product of the virus, from which admixed virus is removed by the chemical treatments. Bacteria in culture may produce specific, filterable by-products, regardless of the culture medium.

The crystalline protein recently isolated from the juice of mosaic tobacco and tomato plants by Stanley (332, 332a) shows a high precipitin titer with virus-immune serum. This crystalline material appears to consist largely of virus-antigen, although it also contains protein of the virus-free tobacco plant (53). The writer has prepared what appears to be the same crystalline protein by precipitating virus-containing phlox juice with tobacco-virus antiserum and then digesting the precipitate with pepsin. The high yield of crystalline protein obtained indicates that the protein is either virus or specific virus by-product, since there are no serologically common proteins in healthy tobacco and phlox (53).

Although it appears from the foregoing facts that the crystalline tobacco mosaic protein and the antigen responsible for the virus-specific precipitin tests are the same thing, the question remains open whether or not this antigen is the virus responsible for the disease. From the practical standpoint, however, this problem does not seriously affect the utility of the virus seric reactions. The empirical evidence indicates that the virus antigens are specific for each type of virus disease and that usually, if not always, there is a direct relationship between amount of virus and amount of antigen in a given preparation. From this point of view, serology has served in the past, and probably has much to offer in the future, in the study of virus diseases of plants and of the nature and action of their causal agencies.

It is thus evident from these illustrations that phytoserology gives promise of being an instructive and valuable objective aid

in plant virus research, as in research on other types of fundamental biological problems.

VIII. THE POSSIBILITIES AND LIMITATIONS OF PHYTOSEROLOGY

It has been the purpose of the present paper thus far to describe the methods and results of serology as applied to plant materials, and to indicate the directions in which serological studies are proving of value in relation to other botanical disciplines. While, however, the results thus far obtained incline one to be rather optimistic as to the value of phytoserology, it must be borne in mind that the serological methods are beset by numerous difficulties both in practice and in interpretation. Great strides have been made in the understanding of serology since the early experiments of Kraus, Tschistovitch, Bordet, and Ehrlich at the end of the 19th century, but in spite of this much is yet to be learned of the principles of general serology. A number of questions of basic importance are unanswered or controversial. For 30 years it was held as unequivocal that proteins were the antigens *par excellence*, yet the recent works of Sachs, Heidelberger, and others tend to make it increasingly evident that lipoids and carbohydrates also have an important part to play in serological reactions. The site of antibody formation is unknown; the relative serological importance of various parts of the antigenic molecule is not wholly clear. Plant serology naturally looks to the older serology of animal and bacterial materials for guidance, and in many cases the older science is not yet able to supply adequate answers to the questions regarding the principles of general serology. The limitations of plant serology are, then, primarily the limitations of all serology, limitations inherent in the growth of any comparatively young science.

In addition, the plant serologist faces many technical and theoretical problems peculiar to plant materials and conditioned by the complexity of these. There are present in plants many substances which disrupt the performance of serological tests. Some of these, e.g. lipoids, are also impediments in animal serology; others, e.g. tannins, plant organic acids, plant alkaloids and glucosides, are peculiar to plants, and, as has been pointed out, these may produce artefact reactions of such intensity as seriously to interfere with the prosecution of serological tests. More and more stress has been laid on the elimination of these in recent years, as is witnessed by the studies of the Königsberg, Münster, and Kiel investigators. But at the present time one can proceed only with the utmost caution in regarding as significant serological reactions in which there is always the possibility of distorting artefact phenomena. Complete control systems must be rigidly adhered to, and experiments in which any of the controls are faulty must be rigorously discarded. Even with careful experimentation a large percentage of experiments may fall into this category.

One does not find in phytoserology a panacea for the troubles encountered as a result of the subjectivity of certain other botanical disciplines. But the handicaps of serology are of types which give promise of yielding more and more to the gradual improvements in technique and advances in interpretation. The only apparently insuperable difficulty lies in the probable inability to immunize animals with plant antigens which are so unstable that they break down in the experimental animal before there is time for them to reach the site of antibody

formation and stimulate the production of antibodies. Certain plant viruses, for example, are highly unstable at mammalian blood temperature, being destroyed in a few minutes at 40°C. Whether or not such may be eventually used with success as antigens remains to be seen. Possibly the substitution of a cold-blooded animal or the treatment of the antigen in such a way as to render it more stable without altering its specificity may serve to eliminate this difficulty. It is not unlikely that many other plant and animal proteins besides the viruses show a similar lack of stability, and remain hitherto undetected because of this fact. It is certain that, in the preparation of plant antigens by the extraction of dried tissues or expression of juices, there must inevitably result extensive and basic changes in the chemical composition of the products originally present in the plant, although future researches may aid materially in lessening these changes.

A question which has frequently arisen in the phytoserological literature is whether the plant proteins are more or less diverse, serologically, than the proteins of animal origin. It seems to the writer that this is a question of much less moment than would be expected from its discussion in the literature. Using blood serum as an antigen it is frequently possible to distinguish species of the same genus. The same is sometimes true of plant serology, using tissue extracts as antigens, but not always. Using such distinct species as many of the Solanaceae, separations are entirely practicable; with such closely related species as many of the fungi, on the other hand, the separation is accomplished with much more difficulty or not at all. This is by no means to be deplored,—in fact, this difference gives us an insight into the relative significance of the concept "species" in the two cases mentioned. Even with the fungi Link has shown that among some fungi, species and even varieties are readily distinguishable, while among other fungus groups it is difficult or impossible even to separate genera of the same family. Blakeslee and Gortner in 1913 (33) even reported that there were able to distinguish + and − strains of *Mucor* species by the precipitin test, although this has never been confirmed. Our natural classification, so-called, is at best an artificial system, the distinctions between species depending not so much on the phylogenetic distance of the forms concerned as on the *differences in morphological structure produced by a given phylogenetic trend*. It may very well be that varietal differences in the Solanaceae represent phylogenetic divergences fully as great as are intimated by specific differences in the genus *Fusarium*. If so, it is well to have serology as an arbitrary guide as to what constitutes a significant phylogenetic departure. An immediate objection to this view is that the protein differences as demonstrated by serological techniques are but a single phase of phylogenetic development. This is true, but there is reason to believe that protein divergences are at the basis of all morphological divergences. As Wells (362) has pointed out, the proteins represent the only chemical substances which could be responsible for the great diversity in life. It is by no means certain that serological reactions give a true picture of the relationships of the proteins responsible for specific, varietal, and individual differences in animals and plants, but it is self-evident that a study of protein relationships comes closer to the fundamental species-specific characteristics of species than the evolutionarily convergent morphological characteristics, such as flower structure and leaf dentition, on which our present systems of plant phylogeny are

based. Assuredly, if one could obtain a precise serological technique for the differentiation of the proteins of the genes, this would afford a more accurate approach to the question of phylogeny than any yet adduced. We cannot be sure how much if any of the serologically active protein of plant antigenic extracts is karyosomal in direct origin. It is significant that the weight of the evidence, however, favors the view that all tissues of a plant have serologically common properties, which would imply a fundamental unity of active material. It is not possible at the present time to do more than suggest the viewpoint that the serological reactions in plants are due in part at least, to materials closely related to or consisting of the karyoprotein, but such a view is favored by the experimental evidence in hand, and such affords excellent reason for regarding the serological reactions as fundamental in the study of the constitutions and relationships of plant species.

Granting such difficulties as those mentioned, the empirical results of phytoserology have shown that in spite of the handicaps the method has proven its usefulness as an adjunct discipline of very different character from those heretofore employed in botanical studies. Chief of its advantages are its objective nature and its fundamental character, objective in the sense that a serological test is positive or negative, opinion having little part to play in its prosecution and evaluation, fundamental in the sense that it is the proteins, the chemical basis of specific differences, which serve as the source of evidence. Because of these facts, it is concluded that in such studies as those of plant phylogeny and systematics, of protein metabolism, and of the detection and identification of plant products, the serological methods have already proven their usefulness and give promise of offering much aid in future investigations in these and related disciplines.

IX. RECAPITULATION

Part I

The present paper presents a digest of the information available regarding the serology of plants and plant products exclusive of bacteria. The techniques of phytoserological procedures are outlined, and then are considered the results of phytoserological investigations as applied in particular to the diagnosis of plants and plant products, the systematics of plants, plant toxicology, contributions of plant serology to the field of general serology and to certain aspects of medicine connected with plant pathogens and toxins, and such basic botanical problems as those of protein metabolism and movement in plants, the constitution of plant hybrids, and the nature and properties of plant viruses.

Rabbits are customarily used in the preparation of immune sera. Immunization- and test-antigens usually consist of solutions of dried, macerated plant tissues in physiological saline, water, phosphate buffers, or weak alkali. It has been found desirable to preëxtract such tissues preliminary to extraction, with ether, alcohol, benzol, acetone, etc., to remove non-specific precipitating substances. For certain purposes expressed saps, suspensions of whole or macerated plants, or purified protein or carbohydrate fractions may be used to advantage. Since many plants contain constituents which precipitate in the presence of normal serum, it is held desirable to eliminate such non-specific reactions by thorough preëxtraction followed by an elimination of any residual normal serum reaction through dilution, absorption of the extracts with

normal serum, or the use of phosphate buffers. While in general all organs of a given plant contain common antigens, the differences in concentration of these and the possibility of the occurrence of organ-specific proteins makes it desirable to confine single experiments to a single type of organ. Chemical protein tests have often been found to bear so little relationship to the amount of serologically active protein present that their value in controlling serological reactions is very limited. A careful standardization of extraction technique is held to be more satisfactory than a subsequent adjustment of extracts to equal protein tests.

It is comparatively easy to immunize to plant toxins so that the animals will tolerate several or many lethal doses of the toxin. The blood of animals thus immunized *by feeding* does not yield precipitating, complement-fixing, or anaphylactic antibodies, however, hence the feeding of herbivorous animals should have little or no effect on the serological reactions of the blood of such animals after injection with plant antigens. Other details of the production of immune sera follow the techniques customarily employed in animal serology.

The artificial sera used by Mez and Ziegenspeck have failed to be satisfactory in the hands of numerous other responsible investigators. Although there is both theoretical and empirical basis for their use, they have not, at least thus far, proven sufficiently reliable to serve in routine phytoserological work.

The precipitin test, the most extensively used technique in phytoserology, may be desirably carried out either by overlaying antigen and serum (ring test) or by mixing the two (flocculation test). The latter test is somewhat more sensitive, the former more convenient. With plant antigens and especially in plant relationship studies, it is highly desirable to use an extensive and complete system of controls, preferably after the order of those used in the laboratory of Mez and described in Part I. Various methods have been used for the determination of strength of reaction, but it is felt that unless reactions are sufficiently sharp that essentially the same results are obtained by any approved method, the results are of doubtful significance.

The so-called "conglutinin reaction" of Mez, better designated as "Mez' reaction," represents a methodological variation of the precipitin reaction, perhaps somewhat more sensitive than the latter, and serving as a useful adjunct to the customary precipitin technique, although looked upon as somewhat less reliable because of the addition of another variable to an already complex system.

The anaphylaxis reaction in various forms has been applied to plant materials with considerable success. It is exceedingly delicate and specific in the form of the Schultz-Dale modification and in this form has yielded valuable evidence as to the antigenic compositions of plant extracts. Toxic plant materials may be studied by this method if the extracts are first dialyzed.

Many plant extracts, particularly plant toxins, are hemolytic, often powerfully so. Immunization frequently results in the production of anti-hemolysins in the blood. Lysis of particulate plant antigens by immune serum has not proven a satisfactory phytoserological procedure, nor has the Abderhalden lytic reaction, but the complement fixation test, which is described in detail, has been found to be the most delicate and specific of all immunological reactions employed in plant serology. Similarly, many plant extracts are hemagglutinating and their use as immunization antigens results in the

production of anti-agglutinative sera. Likewise normal serum not infrequently non-specifically agglutinates particulate plant antigens. The acquired agglutination of such antigens has proven of particular use in the study of unicellular algae and fungi or fungus spores. There is some evidence to support the view that this reaction is due to the antigenic actions of substances in the cell capsule, which may be relatively non-specific, and not to the protoplast itself.

The immunization of animals to plant toxins either by injection or *per os* usually results in a greater or less toleration of such toxins. After repeated injection the blood customarily contains neutralizing antibodies specific for the toxin, and passive protection is possible with such blood. Similarly, a number of the plant viruses if injected into animals induce the production of specific neutralizing antibodies, although the viruses are not pathogenic to the animals used. Other serological tests which have been used with plant antigens without, or with indifferent, success comprise phagocytosis and the opsonic index, the effect of immune serum on the germination of seeds and the growth of plants, decoloration of plant dyes by dye-immune serum, Pfeiffer's test, and antidiastatic power of anti-yeast serum.

Part II

Serology has shown itself highly suitable for purposes of identification of plant products. An important practical application of this is in the identification of contaminants or adulterants of flours, meals, fodders, drugs, etc., especially when the contaminant is toxic or present in illegal quantity. Ricin, field mustard, ergot, corn-cockle, plantain, and potato flour as adulterants or contaminants have been detected by this method.

In seed testing serology has been of less value principally because here varietal differences and provenience of seed samples are of paramount importance, while generic and specific differences are usually easily recognized by the morphology of the seeds. It is often very difficult to differentiate varieties of plants serologically, although in a few cases this has been claimed. Several factors are involved in this problem of specificity.

It is manifest that the botanical family is an arbitrary unit, based on conceptions of homogeneity which may be very different among different orders of plants. It necessarily follows that some families are more compact in an evolutionary sense and consequently more compact serologically. Thus, in some families it has been found that differentiation of genera is impossible serologically, in others genera are distinct but species indistinguishable, until finally species, varieties, and even biological races and sexes may occasionally be separated serologically. The genus or species usually represents the limits of separation, however.

It has become recognized that the plant antigens customarily used represent complexes of many individual antigens (protenoms), and the resulting reactions are mosaics of numerous individual reactions. In two closely related forms the greater number of individual antigens are in common, only a few being distinct. This makes possible the relationship reaction which may be looked on as a group of more or fewer identity reactions according as the number of antibodies corresponding to the several antigen units (protenes) is greater or less. Relationship reactions are, then, the summation of many or few identity reactions with the antigenic units in the protein complex of a plant extract.

The success of Nuttall in deriving animal

relationships by serological methods led to a number of tentative attempts to do the same with plant extracts during the years 1900–1912. This work, chiefly with legumes and grains, was sufficiently successful to warrant the development of the subject on a broad scale. This was done by Mez and his colleagues in Königsberg in the years 1912 to the present. The whole plant kingdom has been studied serologically, and from the results a serological phylogenetic tree, the "Königsberg Stammbaum," has been derived. On the whole this agrees very well with existing systematic conceptions, and in great part has been well received by systematists. The tree, besides bringing out the relationships of the many families involved, exemplifies the unity of life and the absence of convergence in protein evolution.

In 1926 Gilg and Schürhoff in Berlin and their students began a series of papers strongly criticizing the Königsberg studies. The failure of the Berlin school in repeating the Königsberg work is interpreted by the fact that the Berlin techniques differ in a number of important respects from those of the Königsberg school, lacking in certain instances the exactness and sensitivity of the Königsberg methods. A number of independent investigators in Germany, Japan, Holland, and Finland have carefully repeated the Königsberg procedures with selected plant groups and have obtained results confirming the Königsberg Stammbaum and bringing out the fallacies of the Berlin criticism.

In recent years a number of more specialized and restricted sero-diagnostic studies have been undertaken in various other laboratories, the results of which have shown the service of serology in correlation with systematics particularly with regard to such problems as grafting compatibilities, cross-inoculability of legumes with nodule bacteria, disease susceptibility and resistance, possibilities of hybridization, and systematics of such difficult groups as the algae and fungi.

A study of the possible serological reactions of plant non-proteins has brought out the following points: The "water-soluble specific carbohydrates" of yeasts and other fungi are highly active as test antigens but do not themselves induce antibody formation, as a rule. Their specificity is problematical; in some cases, at least, entirely heterogenetic reactions are obtained with them. Certain plant glucosides, notably the toxins of *Amanita*, and poison ivy, appear to induce toleration in animals. Plant alkaloids, starches, chlorophyll and xanthophyll, hematoxylin, and tannins have not in general been found to act satisfactorily as antigens, although they may often be studied serologically by means of their protein contaminations. Pure plant lipoids are non-antigenic in the sense of their inducing antibody-formation, unless bound to proteins, in which case antibodies are formed which react with the pure lipoids *in vitro*. Practically, the plant lipoids may be conveniently studied serologically because of their characteristic protein contaminants.

The yeasts and yeast-like fungi pathogenic to animals give agglutinin, precipitin, and complement fixation tests with the sera of infected or immunized animals, although these forms are often so closely related that differentiation and relationship study are impractical. Hay fever, asthma bronchiale, urticaria, and a dermatitis in workers with satinwood are all due to anaphylactic reactions to plant antigens, and their diagnosis and treatment proceeds logically and effectively from this standpoint. Death in animals when due to antigenic plant toxins may be

accurately diagnosed by serological tests of the toxin residues in stomach and intestinal contents.

As regards certain basic biological problems, serology has been used with success in studying the movement of proteins in plants, although the possibilities in the study of protein metabolism, especially as regards graft-metabolism, mycorrhizal relationships, and acquired immunity in plants, have hardly been sounded. Moritz has shown that the Schultz-Dale anaphylactic test affords valuable evidence as to the nature and constitution of plant hybrids, in comparison serologically with their parents. In the field of plant virus research serology is of continually increasing benefit in connection with the problems of virus relationships and classification, estimation of relative and absolute virus concentration and purity, detection and diagnosis of virus diseases and virus types concerned, movement of virus in the plant, and the nature of the virus particle. Although in this work it has been assumed that it is the virus itself which engenders the reactions, the possibility that the reactions may be due to some specific by-product of virus activity has not been excluded.

The possibilities and limitations of phytoserology are briefly discussed. The main advantages of the method are its sensitivity, its specificity, and its objective character. It is limited at present by a number of inadequacies in technique, which, however, are slowly being minimized or eliminated. The method is significant only when skillfully employed and when the reactions are very rigidly controlled. Given such prerequisites, however, and judging pragmatically, the serological reactions have already served in the solution of a number of important botanical problems, and give promise of far-reaching value as an adjunct to many phases of botany.

LIST OF LITERATURE

(Except as otherwise noted all papers have been consulted in the original.)

(1) Abel, J. J., and W. W. Ford. 1906/07. On the poisons of *Amanita phalloides*. *Jour. Biol. Chem.*, 2: 273–288.

(2) Alderson, H. E. 1922. Treatment of oak dermatitis caused by *Rhus diversiloba*. *Cal. State Jour. Med.*, 20: 153–154.

(3) ——, and H. J. Pruett. 1921. Poison oak dermatitis (a specific treatment). *Cal. State Jour. Med.*, 19: 188–193.

(4) Alexnat, W. 1922. Sero-diagnostische Untersuchungen über die Verwandtschaftsverhältnisse innerhalb der Sympetalen. *Bot. Arch.*, 1: 129–154.

(5) Angelis, G. de. 1909. Sul potere antigeno di alcuni colori vegetali. *Ann. Ig. Sper.*, 29 (N. S.): 33– . (Abst. in *Cbl. Bakt. Ref.* 44: 530–531.)

(6) Ankermann, F. 1927. Die Phylogenie der Monocotyledonen. *Bot. Arch.*, 19: 1–78.

(7) Arms, H. 1928. Versuche mit isolierte Eiweisskörpern aus ölreichen Samen, sog. Edestinen, und ihre Brauchbarkeit in der Phytoserologie. Diss. Berlin, Druck. P. Funk, *Berlin*.

(8) Arzt, H. 1926. Serologische Untersuchungen über die Verwandtschaftsverhältnisse der Gerste mit besonderer Berücksichtigung des Eiweissausgleichs innerhalb der präzipitierenden Lösungen. *Bot. Arch.*, 13: 117–148.

(9) Assmann, F. 1911. Beiträge zur Kenntnis pflanzlicher Agglutinine. *Pflüger's Arch. Ges. Physiol.*, 137: 489–510.

(10) Atlass, J. 1888. Über Senegin. *Arb. Pharm. Inst. Dorpat.*, 1: 57–99.

(11) Axamit, O. 1907. Überempfindlichkeitserscheinungen nach Hefeinjektion. *Arch. f. Hyg.*, 62: 15–54.

(12) Azuma, T. 1910. Beiträge zur pflanzlichen Anaphylaxie. Diss. Pathol.-Bakt. Inst. *Osaka*. (Abst. in *Ztschr. Immunitätsf. Ref.*, 2: 996. 1910.)

(13) Baldwin, I. L., E. B. Fred, and E. G. Hastings. 1927. Grouping of legumes accord-

ing to biological reactions of their seed proteins. Possible explanation of phenomenon of cross inoculation. *Bot. Gaz.*, 83: 217–243.

(14) BALLNER, F. 1910. Über die Differenzierung von pflanzlichem Eiweiss mittels der Komplementbindungsreaktion. *Sitzgsber. K. Akad. Wiss., Wien. Math.-Naturwiss. Kl.*, 119: 17–58.

(15) ——, and R. BUROW. 1911. Studien über die biologische Differenzierung von pflanzlichem Eiweiss. Versuche zur Differenzierung von Leguminosen-Eiweiss und von Varietäten einer und derselben Art. *Innsbruck*, (Selbstverlag). 22 pp. (Abst. in *Bot. Cthl.*, 120: 148–149.)

(16) BALLS, A. K. 1925. The precipitin test in the identification of yeasts. *Jour. Immun.*, 10 797–802.

(17) BÄRNER, J. 1927. Serodiagnostische Verwandtschaftsforschungen innerhalb der Geraniales, Sapindales, Rhamnales und Malvales. *Biblio. Bot.*, Heft 94: 1–39.

(18) BASHFORD, E. F. 1901. Über Blutimmunität. *Arch. Intern. Pharm. Therap.*, 8: 101–109.

(19) ——. 1901. Über Blutimmunität. *Arch. Intern. Pharm. Therap.*, 9: 451–469.

(20) ——. 1903. Note on toxic and antitoxic action *in vitro* and *in corpore*. *Jour. Path. Bact.*, 8: 52–69.

(20a) BAWDEN, F. C. 1935. The relationship between the serological reactions and the infectivity of potato virus "X." *Brit. Jour. Exp. Path.* 16: 435–443.

(20b) ——, and N. W. PIRIE. 1936. Experiments on the chemical behavior of potato virus "X." *Brit. Jour. Exp. Path.* 17: 64–74.

(21) BECK, E. C. 1934. The precipitin ring test applied to some Ustilaginaceae. *Canad. Jour. Res.*, 10: 234–238.

(22) BECKER, H-J. 1932. Die Immunisation mit pflanzlichen Lipoiden und die Störung der Verwandtschaftsreaktionen durch Lipoide. *Bot. Arch.*, 34: 267–286.

(23) BECKER, J. 1918. Serologische Untersuchung von Kornrade in Mehl und Kleie. *Cthl. Bakt.* II, 48: 417–420.

(24) BERG, H. VOM. 1932. Über serologische Organspezifität bei Pflanzen. *Ber. Deut. Bot. Ges.*, 50: 93–99.

(25) BERTARELLI, E. 1902. Il metodo biologico e le sue applicazioni alla diagnosi differenziale delle farine delle leguminose. *Giorn. R. Accad. Med. Torino*, Ser. 4, 8: 489–492.

(26) ——. 1903. Applicazione del metodo biologico alla ricerca ed alla diagnosi delle farine leguminose con speciale reguardo ricerca della veccia. *Riv. d'Igiene e San. Pubbl.*, 14: 643–657.

(27) BERTARELLI, E. 1904. Die Verwendung der biologische Methode zur Auffindung und Diagnose der Hülsenfruchtmehle mit besonderer Berücksichtigung der Wicke. *Cthl. Bakt.* II, 11: 8–13, 45–51.

(28) BIERBAUM, K. 1912. Der Nachweis von Bestandteilen des Rizinussamens in Futtermitteln mit Hilfe der Komplementablenkungsmethode. *Ztschr. Infekkr. Haustiere*, 12: 351–371.

(29) BIRKELAND, J. M. 1934. Serological studies of plant viruses. *Bot. Gaz.* 95: 419–436.

(30) BISSÉRIÉ. 1901. Sérum agglutinant des levures. *C. R. Soc. Biol.*, 53: 199–201.

(31) BITZEK, E. 1928. Der Centrospermenast der Dicotylen. *Bot. Arch.*, 22: 257–384.

(32) BIVINGS, F. L. 1924. Successful desensitization and treatment of poison ivy and poison oak poisoning. *Arch. Derm. and Syph.*, 9: 602–606.

(33) BLAKESLEE, A. F., and R. A. GORTNER. 1913. Chemical differences between the sexes. *In:* "Dept. of exper. evolution", C. B. Davenport. *Yearbook, Carnegie Inst., Washington, D. C.*, 12: 99–100.

(34) ——, and ——. 1915. Reaction of rabbits to intravenous injections of mould spores. *Biochem. Bull.*, 4: 45–51.

(35) BLASS, R. 1930. Serodiagnostische Untersuchungen über die Verwandtschaftsbeziehungen der Dipsacaceae, Cucurbitaceae, Campanulaceae und Compositae zueinander. Diss. Berlin, Druck. P. Funk, *Berlin*.

(36) BOOM, B. K. 1930. Botanisch-serologische onderzoekingen. Diss. *Wageningen*. Veenman & Zonen.

(36a) BOYDEN, A. 1936. Serology and biological problems. *Sigma Xi Quart.*, 24: 152–160.

(37) BROUHA, M. 1901. Sur les propriétés du sérum des cancereux au point de vue des anticorps des levures. *Cthl. Bakt.* I, 30: 945–948.

(38) BRY, H. 1930. Beitrag zur Untersuchung über die systematische Stellung der Empetraceen under Anwendung der botanischen Serodiagnostik. Diss. Berlin., Druck. Särchen, *Berlin*.

(39) BÜRGER, J. 1929. Serologische Parallelversuche zwischen Reserveeiweiss und Plasmaeiweiss. Diss. Berlin, Druck. Särchen, *Berlin*.

(40) Bürger, M. 1914. Studien über die praktische Verwertbarkeit der Anaphylaxie bei Sensibilisierung mit denaturiertem Eiweiss. *Ztschr. Immunf.*, 22: 199–219.

(41) Canonici, C. 1933. Studi sulla fermentazione citrica: Tentativi di differenziazione culturale e sierologica di alcuni ceppi di *Aspergillus niger*. *Riv. Biol.* 15: 280–298.

(42) Cao, G. 1904. Il metodo sierodiagnostico e il riconoscimento dell'amido del frumento, dell'orzo e della segale. *Ann. d'Ig. Sper.*, 14 (N.S.): 83–102.

(43) Castellani, A. 1902. Some experiments on the precipitins. *Lancet*, 1: 1827–1829.

(44) ——. 1923. (Untitled paper on the origin of the science of medical mycology.) *Brit. Med. Jour.*, 2: 238.

(45) Catastini, G. 1905/06. Sulle precipitine dei funghi. *Bull. R. Accad. Med. di Roma*, 1905/06, Fasc. 1/3. (Abst. in *Ctbl. Bakt. Ref.*, 40: 83. 1907.)

(46) Chapman, H. G. 1910. A contribution to the study of the precipitins. *Proc. Linn. Soc. New So. Wales*, 35: 526–554.

(47) Chester, K. Starr. 1934. Specific quantitative neutralization of the viruses of tobacco mosaic, tobacco ring spot, and cucumber mosaic by immune sera. *Phytopath.*, 24: 1180–1202.

(48) ——. 1934. Independence of specific neutralization and precipitin reactions with certain plant viruses. (Unpublished manuscript, Rockefeller Inst. for Med. Res., *Princeton, N. J.*)

(49) ——. 1935 (1934). Serological evidence in the study of the relationships of certain plant viruses. (Abst.). *Phytopath.*, 25: 10.

(50) ——. 1935. Serological evidence in plant-virus classification. *Phytopath.*, 25: 686–701.

(51) ——. 1935. The antigenicity of the plant viruses. *Phytopath.*, 25: 702–714.

(52) ——. 1935. A serological estimate of the absolute concentration of tobacco mosaic virus. *Science*, 82: 17.

(53) ——. 1936. Serological tests with Stanley's crystalline tobacco-mosaic protein. *Phytopath.*, 26: 715–734.

(54) ——. 1936. Separation and analysis of virus strains by means of precipitin tests. *Phytopath.*, 26: 778–785.

(55) ——. 1936. Liberation of neutralized virus and antibody from antiserum-virus precipitates. *Phytopath.*, 26: 949–964.

(56) Citron, J. 1905. Über das Verhalten der Favus- und Trichophytonpilze im Organismus. *Ztschr. Hyg. Infekkr.*, 49: 120–134.

(57) Citron, J. 1923. Die Methoden der Immunodiagnostik, Immuno- und Chemotherapie und ihre praktische Verwertung. Ed. 4. *Leipzig*, Verlag Thieme.

(58) Conradi, A. 1926. Das System der Farne unter Berücksichtigung der Morphologie, Entwicklungsgeschichte, Paläontologie und Serodiagnostik dargestellt. *Bot. Arch.*, 14: 74–137.

(59) Coons, G. H. 1928. Some aspects of the *Fusarium* problem. *In*: Kunkel, L. O. *et al.* Mayo Foundation Lectures. Lectures on Plant Pathology and Physiology in Relation to Man. *Philadelphia* (Saunders): 43–92.

(60) ——, and M. C. Strong. 1928. New methods for the diagnosis of species of the genus Fusarium. *Papers, Mich. Acad. Sci. Arts and Letters*, 9: 65–88.

(61) Corpaci, A. 1925. Reazioni immunitarie nelle Aspergillosi. *Boll. Ist. Sieroterap. Milan*, 4: 295–306.

(62) Cushny, A. R. 1898. Über das Ricinusgift. *Arch. Exp. Path. Pharm.*, 41: 439–448.

(63) Davidson, A. M., P. H. Gregory, and A. R. Birt. 1934. A clinical and mycological study of suppurative ringworm. *Canad. Med. Ass. Jour.*, 31: 587–591.

(64) Defalle, W. 1902. Recherches sur le rôle de l'enveloppe des microbes dans l'agglutination. *Ann. Inst. Past.*, 16: 595–613.

(65) Delezenne, C., H. Mouton, and E. Pozerski. 1906. Sur l'allure anomale de quelques protéolyses produites par la papaïne. *C. R. Soc. Biol.*, 60: 68–70.

(66) ——, ——, and ——. 1906. Sur la digestion brusque de l'ovalbumine et du sérum sangui par la papaïne. *C. R. Soc. Biol.*, 60: 309–312.

(67) Diels, L. 1924 (1920). Die Methoden der Phytographie und der Systematik der Pflanzen. (Serologische Merkmale). *Abderh. Handb. Biol. Arbmeth.*, Abt. XI, 1: 131–132.

(68) Dunbar, W. P. 1903. Zur Frage betreffend die Aetiologie und specifische Therapie des Heufiebers. *Berl. Klin. Wschr.*, 40: 537–539, 569–572, 596–599.

(69) ——. 1910. Über das serobiologische Verhalten der Geschlechtzellen. *Ztschr. Immunf.*, 4: 740–760; 7: 454–497.

(70) Dvorak, M. 1927. The effect of mosaic on the globulin of potato. *Jour. Infect. Dis.*, 41: 215–221.

(71) Edgecombe, A. E. 1931. Immunological relationship of wheats resistant and susceptible to *Puccinia rubigo-vera triticina*. *Bot. Gaz.*, 91: 1–21.

(72) Ehrlich, P. 1891. Experimentelle Untersuchung über Immunität. I. Über Ricin. II. Über Abrin. *Deut. Med. Wschr.*, 1891, Nos. 32, 44. Reprinted in: Constitution, Vertheilung und Wirkung chemischer Körper. Ältere und neuere Arbeiten von Paul Ehrlich. *Leipzig*, Verlag Thieme, 1893: 81–96.

(73) ——. 1897. Zur Kenntnis der Antitoxinwirkung. *Fortschritte der Med.*, No. 2, Jan. 15, 1897: 41–43.

(74) Eisenträger, O. 1928. Untersuchungen über die Brauchbarkeit der Serodiagnostik für die Verwandtschaftsforschung in der Botanik, insonderheit innerhalb der Klasse der Gymnospermen, usw. *Beitr. Biol. Pfl.*, 16: 157–216.

(75) Eisler, M. 1927. Versuche zur Erzeugung künstlicher Immunsera nach Mez und Ziegenspeck. *Ztschr. Immunf.*, 53: 136–150.

(76) Eisler, M. von, and L. von Portheim. 1908. Über ein Hämagglutinin im Samen von *Datura*. *Ztschr. Immunf.*, 1: 151–160.

(77) ——, and ——. 1911. Über Hämagglutinine in Pflanzen. *Ber. Deut. Bot. Ges.*, 29: 419–430

(78) ——, and ——. 1911. *Cbl. f. Biochemie*, 12: 391.

(79) Elfstrand. 1898. Über blutkörperchenagglutinierende Eiweisse. *Görbersdorfer Veröffentl.*, 1: 1–103. (*Stuttgart.*)

(80) Elmore, M. E. 1928. Antigenic properties of *Euglena gracilis*. *Jour. Immun.*, 15: 20–32.

(81) ——. 1928. Anaphylaxis VIII. The production of anaphylaxis with *Euglena gracilis* and certain other unicellular chlorophyll-bearing organisms. *Jour. Immun.*, 15: 33–36.

(82) Elsesser, O. J. 1916. The specificity of the Abderhalden reaction with vegetable proteins. The biologic reactions of the vegetable proteins VIII. *Jour. Infect. Dis.*, 19: 655–681.

(83) Farah, N. 1923. Observations on Castellani's bronchomoniliasis, with report of a case with pneumonic onset and a peculiar clinical course. *Jour. Trop. Med. Hyg.*, 26: 1–5.

(84) Fellmer, T. 1914. Differenzierung verschiedener Pilzeiweiss mit Hilfe von Immunitätsreaktionen und Tierversuchen. *Ztschr. Immunf.*, 22: 1–30.

(85) Ford, W. W. 1906. The toxicological constitution of *Amanita phalloides*. *Jour. Exp. Med.*, 8: 437–450.

(86) ——. 1906. The toxins and antitoxins of poisonous mushrooms. (*Amanita phalloides*). *Jour. Infect. Dis.*, 3: 191–224.

(87) Ford, W. W. 1907. Antibodies to glucosides, with especial reference to *Rhus toxicodendron*. *Jour. Infect. Dis.*, 4: 1–11.

(88) ——. 1907. On the presence of hemolytic substances in edible fungi. *Jour. Infect. Dis.*, 4: 434–439.

(89) ——. 1908. Artificial immunity to glucosides. *Science*, N.S., 27: 652–657.

(90) ——. 1909. Note on *Rhus toxicodendron*. *N. Y. Med. Jour.*, July 31, 1909. 2 pp.

(91) ——. 1909/10. The distribution of poisons in the Amanitas. *Jour. Pharm. Exp. Therap.*, 1: 275–287.

(92) ——. 1910/11. On the toxicology of the tutu plant. *Jour. Pharm. Exp. Therap.*, 2: 73–85.

(93) ——. 1910/11. Further observations on the immunisation of animals to the poisons in fungi. *Jour. Pharm. Exp. Therap.*, 2: 145–152.

(94) ——. 1910/11. The distribution of haemolysins, agglutinins, and poisons in fungi, especially the Amanitas, the Entylomas, the Lactarius, and the Inocybes. *Jour. Pharm. Exp. Therap.*, 2: 285–318.

(95) ——, and J. L. Sherrick. 1910/11. On the properties of several species of the Polyporaceae and of a new variety of Clitocybe, *Clitocybe dealbata sudorifica* Peck. *Jour. Pharm. Exp. Therap.*, 2: 549–558.

(96) Franz, C. 1928. Die Brauchbarkeit der Serodiagnostik für die botanische Verwandtschaftsforschung mit besonderer Berücksichtigung der Monocotyledoneen. Diss. Berlin, Druck., P. Funk, *Berlin*.

(97) Friedberger, E., and G. A. Brossa. 1912. Über die Wirkung von Pilzextracten. Wirkung der Extracte von Champignon (*Agaricus campestris*), Steinpilz (*Boletus edulis*) und Pfefferling (*Cantarellus cibarius*) auf rote Blutkörperchen. *Ztschr. Immunf.*, 15: 506–517.

(98) Galli-Valerio, B., and M. Bornand. 1912. Quelques recherches avec un sérum précipitant pour l'albumine du tournesol (*Helianthus annuus* Linn.) *Ztschr. Immunf.* I, 15 229–237.

(99) ——, and ——. 1913. Note sur un sérum précipitant pour l'albumine d'*Agaricus muscarius*, Linn. *Ztschr. Immunf.* I, 17: 180–185.

(100) Gasis, D. 1908. Über die Unterscheidung verschiedener Pflanzeneiweissarten mit Hilfe spezifischer Sera. *Berl. Klin. Wschr.*, 45: 358–360.

(101) Gilg, E., and P. H. Schürhoff. 1926. Die Serodiagnostik in der Verwandtschaftsforschung. *Bot. Jahrb.*, 60: 439–450.

(102) Gilg, E., and P. H. Schürhoff. 1927. Unsere Erfahrungen über die Brauchbarkeit der Serodiagnostik für die botanische Verwandtschaftsforschung. *Ber. Deut. Bot. Ges.*, 45: 315–330.

(103) ——, and ——. 1927. Antikritisches zur Kritik von Mez zu unserer Veröffentlichung: Unsere Erfahrungen über die Brauchbarkeit der Serodiagnostik für die botanische Verwandtschaftsforschung. *Ber. Deut. Bot. Ges.*, 45: 602–606.

(103a) Giovanardi, A. 1935. Sul potere antigene del glicogene e dell'amido. *Boll. Soc. Ital. Biol. Sper. 1935*, No. 9: 777.

(104) Gohlke, K. 1913. Die Brauchbarkeit der Serum-Diagnostik für den Nachweis zweifelhafter Verwandtschaftsverhältnisse im Pflanzenreiche. *Stuttgart* and *Berlin*, Verlag Fr. Grub. 190 pp.

(105) Görner, W. 1929. Serologische Untersuchungen über die Actinidiaceae mit besonderer Berücksichtigung ihrer Stellung im System. Diss. *Berlin*. 44 pp.

(106) Gratia, A. 1933. Pluralité antigénique et identification sérologique des virus des plantes. *C. R. Soc. Biol.*, 114: 923–924.

(107) ——. 1933. Qualité antigénique des virus des plantes et des bactériophages. *C. R. Soc. Biol.*, 114: 925–926.

(108) ——. 1933. Pluralité, hétérogénéité, autonomie antigénique des virus des plantes et des bactériophages. *C. R. Soc. Biol.*, 114: 1382–1383.

(109) ——. 1934. Identification sérologique et classification des virus des plantes. Distinction entre l'antigène mosaïque et l'antigène vegetal. *C. R. Soc. Biol.*, 115: 1239–1241.

(110) ——. 1935. Bactériophage et virus des plantes. *Bull. Acad. Roy. de Med. de Belg.* Séance de 4 Mai, 1935: 208–219.

(111) ——, and P. Manil. (1934) 1935. Les complexes de virus des plantes et la méthode sérologique. *C. R. Soc. Biol.*, 117: 493–494.

(112) ——, and ——. (1934) 1935. Différenciation sérologique des virus X et Y de la pomme de terre chez les plantes infectées ou porteuses de ces virus. *C. R. Soc. Biol.*, 117: 490–492.

(113) ——, and ——. 1935. De quelques échecs de la méthode sérologique appliquée aux virus des plantes. *C. R. Soc. Biol.*, 118: 379–381.

(114) Green, F. 1926. The precipitin reaction in relation to grafting. *Genetics*, 11: 73–82.

(115) Grenda, A. 1926. Über die systematische Stellung der Isoetaceen. *Bot. Arch.*, 16: 268–296.

(116) Grijns, G. 1928. De serologische methoden in de botanische systematiek. Voorloopige mededeeling over kunstmatig specifiek serum. *Versl. K. Acad. Wetensch., Amsterdam. Afd. Natuurk.*, 37: 918–923.

(117) Guttmann, F. 1924. Sero-diagnostische Untersuchungen über die Verwandtschaftsverhältnisse innerhalb der Archegoniatae. *Bot. Arch.*, 6: 421–457.

(118) Hannig, E. 1929 (1928). Über experimentelle Systematik der Blütenpflanzen. *Sitzgsber. Naturhist. Ver. Preuss. Rheinl. u. Westfal.*, 1929 (1928): (2)–(16).

(119) ——, and W. Slatmann. 1928. Phytoserologische Untersuchungen. I. Über die Ausschaltung der "Normalringe" an der Schichtfläche zwischen Antigen und Normalserum bei der Präzipitinringmethode. *Planta*, 5: 135–160.

(120) Heidelberger, M., O. T. Avery, and W. F. Goebel. 1929. A "soluble specific substance" derived from gum arabic. *Jour. Exp. Med.*, 49: 847–857.

(121) Heintze, A. 1927. Cormophyternas Fylogeni. (Phylogenie der Cormophyten.) *Lund*, Håkan Ohlssons Boktryckeri.

(122) Hellin, H. 1891. Der giftige Eiweisskörper Abrin und seine Wirkung auf das Blut. Diss., Dorpat, Druck. H. Laakmann, *Dorpat*.

(123) Helwig, B. 1927. Serodiagnostische Verwandtschaftsforschungen innerhalb des Mez'schen Centrospermen. *Biblio. Bot.*, 94: 43–83.

(124) Herzfeld, E. 1915. Zur Frage der Spezifität bei der A. R. *Deut. Med. Wschr.*, 41: 1151–1152.

(125) Hiki, Y. 1922. Beiträge zu serologischen Untersuchungen über das enteral und parenteral eingeführte, artfremde Eiweiss. *Sci. Repts. Govt. Inst. Infect. Dis., Tokyo Imp. Univ.*, 1: 163–191.

(126) Hines, L. E. 1924. Studies on the identification of *Monilia psilosis*. *Jour. Infect. Dis.*, 34: 529–535.

(127) Hirsch, P. 1919. Immunochemische Studien. I. Untersuchungen über Rizin mittels des Interferometers. *Fermentforschung*, 2: 269–289.

(128) Hôdyô, H. 1931. Immunologische Untersuchungen über Blattpresssäfte und Blattfarbstoffe. *Jour. Biochem.*, 13: 273–289.

(129) Hoeffgen, F. 1922. Sero-diagnostische Untersuchungen über die Verwandtschaftsverhältnisse innerhalb des Columniferen-Astes der Dicotylen. *Bot. Arch.*, 1: 81–99.

(130) Hoepner, W. 1930. Wie verhält sich die Serodiagnostik zu den bisherigen Untersuchungen über die systematische Stellung der Callitrichaceen? Diss. Berlin, Druck. Funk, *Berlin*.

(131) Huhn, R. 1927. Über die Verwertbarkeit der Serodiagnostik in der Botanik, erläutert an den Sympetalen. *Beitr. Biol. Pfl.*, 15: 228–262.

(132) Inomata, Y. 1910. Über die durch Pflanzensamen hervorgerufener Überempfindlichkeit. *Saikingaku Zasshi*, M-43, No. 173: 52–71. (Abst. in *Ztschr. Immunf.* Ref., 1910: 760.)

(133) Ishiwara, F. 1923. Differenzierung von verschiedenen Eiweissarten durch die Abderhalden'sche Reaktion, besonders von verschiedenen Harneiweissen. *Ztschr. Immunität. Exp. Therap.*, 37: 238–248.

(134) Jacoby, M. 1902. Über Ricin-Immunität. *Beitr. Chem. Phys. Path.*, 1: 51–77.

(135) ——. 1908/09. Antiricin, Antiabrin, Anticrotin. In: Kraus and Levaditi, Handb. Tech. Meth. Immunf., 2: 255–262.

(136) Janchen, E. 1912. Die Anwendung der Komplementbindungsmethode zur Ermittlung natürlicher Verwandtschaft von Tieren und Pflanzen. *Mitt. Naturwiss. Ver. Univ. Wien*, 10: 74–76.

(137) ——. 1913. Die Methoden der biologischen Eiweissdifferenzierung in ihre Anwendung auf die Pflanzensystematik. *Mitt. Naturwiss. Ver. Univ. Wien*, 11: 1–21.

(138) Jaretzky, R. 1931. Biologisch-chemische Methoden in der stammesgeschichtlichen Verwandtschaftsforschung (Serologie u. a.). *Arch. Pharm.*, 269: 50–62.

(139) Jena, E. 1924 (1921). Verfahren zur Gewinnung von den Immunkörpern ähnlichen Stoffen. Patentschr. (Deut. Reich) 392055, Kl. 30 h, Gruppe 6.

(140) Jones, D. B., and C. E. F. Gersdorff. 1923. Proteins of the cantaloupe seed, *Cucumis melo*. Isolation of a crystalline globulin, and a comparative study of this globulin with the crystalline globulin of the squash seed, *Cucurbita maxima*. *Jour. Biol. Chem.*, 56: 79–96.

(141) Jukna, G. 1890. Über Condurangin. *Arb. Pharm. Inst. Dorpat*, 4: 81–159.

(142) Kanahara, S. 1912. Über Reiseiweisspräzipitine. Ber. III, Jap. Med. Generalversamml. (Abst. in *Ztschr. Immunf.* Ref., 1912: 963.)

(143) Karasawa, M. 1910. Über Anaphylaxie, erzeugt mit pflanzlichem Antigen. *Ztschr. Immunf.*, 5: 509–515.

(144) Kato, S., and Y. Maruyama. 1928. Serodiagnostic investigation on the affinities of different varieties of rice. *Bul. Sci. Fak. Terkul., Kjusu Imp. Univ., Fukuoka, Japan*, 3: 16–29.

(145) Kesten, H. D., D. H. Cook, E. Mott, and J. W. Jobling. 1930. Specific polysaccharides from fungi. *Jour. Exp. Med.*, 52: 813–822.

(146) Kirstein, K. 1922. Sero-diagnostische Untersuchungen über die Verwandtschaften innerhalb der Pflanzengruppe der Gymnospermae. *Bot. Arch.*, 2: 57–79.

(147) Kobert, R. 1891. Über *Abrus precatorius* L. *Sitzgsber. Naturforsch. Ges. Dorpat*, 9: 114–117.

(148) ——. 1891. Über Pilzvergiftung. *St. Petersburger Med. Wschr.*, 16 (= N.S. 8): 463–466, 471–474.

(149) ——. 1902. Lehrbuch der Intoxikationen. Ed. 2. *Stuttgart*, Verlag Enke.

(150) ——. 1913. Beiträge zur Kenntnis der vegetabilischen Hämagglutinine. *Landwirtschaftl. Versuchssta.*, 79: 97–205.

(151) Kohz, K. 1923. Sero-diagnostische Untersuchungen über die Verwandtschaften innerhalb des Rosales-Astes der Dikotylen. *Bot. Arch.*, 3: 30–60.

(152) Kojima, H. 1921/22. Serobiologische Untersuchungen über die Verwandtschaftsverhältnisse zwischen den Dikotyledonen und Gymnospermen. *Mitt. Med. Fak. K. Kyushu Univ., Fukuoka, Japan*, 6: 223–254.

(153) Köketsu, R. 1917. Serodiagnostische Untersuchungen über die Verwandtschaftsverhältnisse der Gymnospermen. *Mitt. Med. Fak. K. Univ. Kyushu*, 4: 61–130.

(154) ——. 1917. Serodiagnostische Untersuchungen an den Gymnospermen. *Bot. Mag. Tokyo*, 31: 144–153.

(155) Komatsubara, K. 1922. Studien über die Phyto-haemagglutinine. *Mitt. Med. Ges. Tokyo*, 36: 72–73.

(156) Kostoff, D. 1934. Inheritance of natural immunity in plants with special reference to breeding of immune varieties. *Ztschr. Zücht., A, Pflanzenzücht.*, 19: 552.

(157) Kowarski, A. 1901. Über den Nachweis von pflanzlichem Eiweiss auf biologischem Wege. *Deut. Med. Wschr.*, 27: 442.

(158) Kraus, R. 1902. Zur Theorie der Agglutination. *Ztschr. f. Heilk.*, 23: 369–390.

(159) ——, L. von Portheim, and T. Yamanouchi. 1907. Biologische Studien über Immunität bei Pflanzen. I. Untersuchungen über die Aufnahme präzipitierbarer Substanz bei

höhere Pflanzen. *Ber. Deut. Bot. Ges.*, 25: 383–388.

(160) KRITSCHEWSKY, J. L. 1914. Über bakterielle Agglutinine und Präzipitine vegetabilischer Herkunft im Zusammenhang mit der Frage über die Fähigkeit der Pflanzen, Immunitätskörper zu produzieren. *Ztschr. Immunf.*, 22: 381–395.

(161) ——. 1915. Über die Eigenschaften bakterieller Agglutinine und Präzipitine vegetabilischer Herkunft. *Ztschr. Immunf.*, 23: 331–357.

(162) KROHN, V. 1933. Eine serodiagnostische Nachprüfung der Sympetalen der Königsberg Stammbaumes. *Ann. Bot. Soc. Zool.-Bot. Fenn., Vanamo*, 4(9). 42 pp. See also *Bot. Arch.*, 37 (1935): 328–372.

(163) KRUSKAL, N. 1891. Über einige Saponinsubstanzen. *Arb. Pharm. Inst. Dorpat*, 6: 1–88.

(164) ——. 1891. Über *Agrostemma Githago*, L. *Arb. Pharm. Inst. Dorpat*, 6: 89–145.

(165) KUBEŠ, V. 1927. La question de la spécificité des organes, de l'influence de divers sérums sur la germination et de l'anaphylaxie des végétaux. *Publ. Biol. de l'École des Hautes Études Veter., Brno, Czechoslov.*, 6: 39–66.

(166) KUROTCHKIN, T. G. 1929. Differentiating fungi by precipitation test with water-soluble specific substances. *Lignan Sci. Jour.*, 7: 163–166.

(167) ——, and C. K. CHU. 1929. Bronchomoniliasis. Serological studies on a case. *Natl. Med. Jour. China*, 15: 403–409.

(168) LAKE, G. C., T. B. OSBORNE, and H. G. WELLS. 1914. The immunological relationship of hordein of barley and gliadin of wheat as shown by the complement fixation, passive anaphylaxis, and precipitin reactions. The biological reactions of the vegetable proteins IV. *Jour. Infect. Dis.*, 14: 364–376.

(168a) LAMB, J. H., and M. L. LAMB. 1935. A grouping of the Monilias by fermentation and precipitin reactions. *Jour. Infect. Dis.*, 56: 8–20.

(169) LANDFESTER, H. 1933. Die Phylogenie des Polyergidae-Astes der Chlorophyceen. *Bot. Arch.*, 35: 307–350.

(170) LANDSTEINER, K., and H. RAUBITSCHEK. 1908. Beobachtungen über Hämolyse und Hämagglutination. *Ctbl. Bakt.* I, 45: 660–667.

(171) ——, and R. STANKOVIC. 1906. Über die Adsorption von Eiweisskörpern und über Agglutininverbindungen. *Ctbl. Bakt.* I, 41: 108–117.

(172) LANGE, L. 1924. Sero-diagnostische Untersuchungen über die Verwandtschaften innerhalb der Pflanzengruppe der Ranales. *Bot. Arch.*, 5: 413–434.

(173) LAU, C. 1901. Über vegetabilische Blutagglutinine. Diss. Rostock, Druck. Boldt, *Rostock*.

(174) LEWIS, J. H., and H. G. WELLS. 1925. The immunological properties of alcohol-soluble vegetable proteins. The biological reactions of the vegetable proteins IX. *Jour. Biol. Chem.*, 66: 37–48.

(175) ——, ——, W. F. HOFFMAN, and R. A. GORTNER. 1924. An immunological and chemical study of the alcohol-soluble proteins of cereals. *Proc. Soc. Exp. Biol. Med.*, 22: 185–187.

(176) LIESKE, R. 1916. Serologische Studien mit einzelligen Grünalgen. *Sitzgsber. Heidelberger Akad. Wiss., Math.-Naturwiss. Kl.*, Abt. B-3. 47 pp.

(177) LINDEN, A. VAN DER. 1926. Sur l'action pathogène du *Monilia albicans*. *C. R. Soc. Biol.*, 95: 881–883.

(178) LIM, C. E., and T. J. KUROTCHKIN. 1930. A study on the serological relationship among yeast-like fungi. *Natl. Med. Jour. China*, 16: 338–346.

(179) LINK, G. K. K. 1918. Bacteria in relation to plant diseases. Chap. XLIV of "The newer knowledge of bacteriology and immunology." Jordan and Falk, Univ. Chicago Press. pp. 590–606.

(180) ——, A. DE S. LINK, G. L. CROSS, and H. W. WILCOX. 1932. The precipitin ring test as applied to fungi. *Proc. Soc. Exp. Biol. Med.*, 29: 1278–1281.

(181) ——, and H. W. WILCOX. 1933. Precipitin-ring test applied to fungi II. *Bot. Gaz.*, 95: 1–34.

(182) LONDINI, A. 1909. Sulla possibilità di ottenere delle precipitine specifiche per i grassi. *Atti R. Accad. Fisiocrit. Siena*, Ser. 5, 1: 933–936.

(183) LÖWENSTEIN, E. 1901. Über die Bedeutung der cellulären Immunität. *Prag. Med. Wschr.*, 26: 374–375.

(184) LUSINI, V. 1905. Di un siero precipitante per l'oppio. *Atti R. Accad. Fisiocrit. Siena*, Ser. 4, 17: 25–29.

(185) ——. 1910. Esperienze sulla siero-reazione precipitante in farmacologia. *Atti R. Accad. Fisiocrit. Siena*, Ser. 5, 2: 147–155.

(186) ——, and G. MEI-GENTILUCCI. 1907. Sul valore della reazione biologica nella farmaco-

logia. *Atti R. Accad. Fisiocrit. Siena*, Ser. 4, 19: 295–309.

(186a) Maass, Th. A. 1935. Über-Empfindlichkeit (Idiosynkrase, Allergie, etc.). *Tab. Biol. Period.*, 5: 1–119.

(187) Magnus, W. 1908. Weitere Ergebnisse der Serum-Diagnostik für die theoretische und angewandte Botanik. *Ber. Deut. Bot. Ges.*, 26a: 532–539.

(188) ——, and H. Friedenthal. 1906. Ein experimenteller Nachweis natürlicher Verwandtschaft bei Pflanzen. *Ber. Deut. Bot. Ges.*, 24: 601–607.

(189) ——, and ——. 1907. Über die Specificität der Verwandtschaftsreaktion der Pflanzen. *Ber. Deut. Bot. Ges.*, 25: 242–247.

(190) ——, and ——. 1907. Über die Artspecificität der Pflanzenzelle. *Ber. Deut. Bot. Ges.*, 25: 337–340.

(191) ——, and ——. 1910. Verhalten sich die somatischen und Geschlechtszellen der Pflanzen serobiologisch wie artfremde Zellen? *Ztschr. Immunf.*, 5: 505–508.

(192) Malligson, F. 1922. Serodiagnostische Untersuchungen über die Verwandtschaften innerhalb des Centrospermen-Astes des Pflanzenreiches. *Bot. Arch.*, 1: 2–20.

(193) Malvoz, E. 1901. Sur les propriétés du sérum des animaux traités par les blastomycètes. *Ctbl. Bakt.* I, 29–688–693.

(193a) Manil, P. 1934. Note sur les nécroses foliaires du tabac dans les cultures de la Vallée de la Semois, en 1934. *Bull. Inst. Agron. et Stat. Rech. de Gembloux, Belg.*, 3: 367–377.

(193b) ——. 1936. A propos d'un sérum bivalent, préparé contre des virus phytopathogènes. *Bull. Inst. Agron. et Stat. Rech. de Gembloux, Belg.*, 5: 96.

(193c) ——. 1936. A propos de la transmission par les graines de certains virus pathogènes. *Bull. Inst. Agron. et Stat. Rech. Gembloux. Belg.*, 5: 96–98.

(194) Manteufel, P. 1928. Serologische Verfahren der Nahrungsmitteluntersuchung. *Abderh. Handb. Biol. Arbmeth.*, Abt. IV, Teil 8, 2: 1809–1918.

(195) Marcusson-Begun, H. 1926. Untersuchungen über das Hämagglutinin der Kartoffelknolle. *Ztschr. Immunf.*, 45: 49–73.

(196) Maschmeier, W. 1927. Versuche über die Möglichkeit einer serologischen Sortendifferenzierung bei der Kartoffel. Diss. Berlin, Druck. des Lindenhofes, *Berlin*. 38 pp.

(197) Matsumoto, T. 1928. Preliminary note on some serological studies of Aspergilli. *Phytopath.*, 18: 691–696.

(198) ——. 1929. The investigation of Aspergilli by serological methods. *Trans. Brit. Mycol. Soc.*, 14: 69–88.

(199) ——. 1929. On the diagnosis of certain plant-infectious diseases by means of serological reactions. *Jour. Soc. Trop. Agr.*, 1: 14–22.

(200) ——. 1930. Antigenic properties of tobacco mosaic juice. Contr. Phytopath. Lab. Taihoku Imp. Univ. 3. *Jour. Soc. Trop. Agr.*, 1: 291–300.

(201) ——. 1932. Early diagnosis of plant diseases. *Trans. Nat. Hist. Soc. Formosa*, 22: 406–407.

(201a) ——. 1935. Differentiation of two petunia mosaic diseases by means of serological, cytological, and inoculation experiments. *Bot. and Zool. (Japan)*, 3: 893–898.

(201b) ——. 1936. Serological analysis of the infective agents causing tobacco mosaic with malformed flowers. *Trans. Nat. Hist. Soc. Formosa*, 26: 258–261.

(201c) ——, and S. Hirane. 1935. Immunological studies of mosaic diseases. V. Microserological tests as a means of detecting the virus in a small area of mosaic tobacco plants. *Jour. Soc. Trop. Agr.*, 7: 346–350.

(202) ——, and K. Somazawa. 1930. Immunological studies of mosaic diseases. I. Effect of formolization, trypsinization, and heat inactivation on the antigenic properties of tobacco mosaic juice. Part I. *Jour. Soc. Trop. Agr.*, 2: 223–234.

(203) ——, and ——. 1931. Same, Part II. *Jour. Soc. Trop. Agr.*, 3: 24–33.

(204) ——, and ——. 1932. Immunological studies of mosaic diseases. II. Distribution of antigenic substance of tobacco mosaic in different parts of host plants. *Jour. Soc. Trop. Agr.*, 4: 161–168.

(205) ——, and ——. 1933. Immunological studies of mosaic diseases. III. Further studies on the distribution of antigenic substance of tobacco mosaic in different parts of host plants. *Jour. Soc. Trop. Agr.*, 5: 37–43.

(206) ——, and ——. 1934. Immunological studies of mosaic diseases. IV. Effects of acetone, lead subacetate, barium hydroxide, aluminium hydroxide, trypsin, and soils on the antigenic property of tobacco mosaic juice. *Jour. Soc. Trop. Agr.*, 6: 671–682.

(207) McKinney, M. J. 1929. Yeast-like organisms of human origin. *Jour. Infect. Dis.*, 44: 47–55.

(208) Mendel, L. B. 1909. Observations on vegetable haemagglutinins. *Arch. di Fisiol.*, 7: 168–177.

(209) Meyer, F. 1929. Serologische Studien über Gattungsbastarde, Pfropfbastarde und Artbastarde. *Beitr. Biol. Pfl.*, 17: 301–350.

(210) Mez, C. 1922. Anleitung zu serodiagnostischen Untersuchungen für Botaniker. *Bot. Arch.*, 1: 177–200.

(211) ——. 1924. Serum-reaktionen zur Feststellung von Verwandtschaftsverhältnissen im Pflanzenreich. *Abderh. Handb. Biol. Arbmeth.*, Abt. IX, Teil I: 1059–1094.

(212) ——. 1925. Drei Vorträge über die Stammesgeschichte der Pflanzenwelt. *Naturwiss. u. Landwirtsch.*, 4: (Abst. in *Bot. Echo*, 1: 14–15, by Steinecke).

(213) ——. 1926. Die Bedeutung der experimentellen Systematik für die stammesgeschichtliche Forschung. *Leopoldina: Ber. K. Deut. Akad. Naturforsch. Halle*, 2: 132–159.

(214) ——. 1926. Die Bedeutung der Sero-diagnostik für die stammesgeschichtliche Forschung. *Bot. Arch.*, 16: 1–23.

(215) ——. 1926. Zur Erklärung der Fremdeiweisstherapie. *Münch. Med. Wschr.*, 73: 1832–1833.

(216) ——. 1926. Serodiagnostic methods applied to drug examination. *Proc. Intern. Congr. Pl. Sci., Ithaca, N. Y.*, 2: 1402–1405.

(216a) ——. 1928. Discussion of: Tischler, G. Über die Verwendung der Chromosomenzahlen für phylogenetische Probleme bei den Angiospermen. *Biol. Ctbl.*, 48: 321–345. *Bot. Arch.*, 22: 574–576.

(216b) ——. 1936. Morphologie und Serodiagnostic, erläutert an Blüte und Blütenstand vom Irreversibilitätsgesetz aus gesehen. *Bot. Arch.*, 38: 86–104.

(217) ——, and K. Gohlke. 1914. Physiologisch-systematische Untersuchungen über die Verwandtschaften der Angiospermen. *Beitr. Biol. Pfl.*, 12: 155–180.

(218) ——, and K. Kirstein. 1920. Sero-diagnostische Untersuchungen über die Gruppe der Gymnospermae. *Beitr. Biol. Pfl.*, 14: 145–148.

(219) ——, and L. Lange. 1914. Sero-diagnostische Untersuchungen über die Verwandtschaften innerhalb der Pflanzengruppe der Ranales. *Beitr. Biol. Pfl.*, 12: 218–222.

(220) Mez, C., and A. Preuss. 1914. Sero-diagnostische Untersuchungen über die Verwandtschaften innerhalb der Pflanzengruppe der Parietales. *Beitr. Biol. Pfl.*, 12: 347–349.

(221) ——, and H. Ziegenspeck. 1925. Zur Theorie der Sero-diagnostik. *Bot. Arch.*, 12: 163–202.

(222) ——, and ——. 1926. Der Königsberger serodiagnostische Stammbaum. *Bot. Arch.*, 13: 483–485.

(223) Michaelis, L., and K. Steindorf. 1906. Über die Wirkung des Rizins auf Serum und Organzellen *in vitro*. *Biochem. Ztschr.*, 2: 43–51.

(224) Michel, C. 1917. A study of toxins and the serological reactions in sprue. *Am. Jour. Med. Sci.*, 154: 177–181.

(225) Mielinski, K. 1926. Über die Phylogenie der Bryophyten mit besonderer Berücksichtigung der Hepaticae. *Bot. Arch.*, 16: 23–118.

(226) Miessner. 1909. Über die Giftigkeit der Ricinussamen. *Mitt. Kaiser Wilhelms Inst. f. Landwirtsch. in Bromberg*, 1: 217–265.

(227) ——, and Rewald. 1909. Die Konglutination der roten Blutkörperchen durch Ricinussamen. *Ztschr. Immunf.*, 2: 323–349.

(228) Mischke, W. 1925. Sero-diagnostische Untersuchungen über strittige Verwandtschaftsverhältnisse innerhalb der Gymnospermen und über den Anschluss von Ceratophyllum. *Bot. Arch.*, 11: 104–145.

(228a) Molisch, H. 1933. Pflanzenchemie und Pflanzenverwandtschaft. *Jena* (G. Fischer). 118 pp.

(229) Mooser, W. 1911. Der Nachweis giftiger Rizinusbestandteilen in Futtermitteln. *Landwirtsch. Versuchs-Sta.*, 75: 107–134.

(230) Moritz, O. 1928. Zur Kritik der Phytoserologie. *Biol. Ctbl.*, 48: 431–443.

(231) ——. 1929. Betrachtungen zum "Ende" der botanischen Serodiagnostik. *Beih. Bot. Ctbl.*, 46(II): 114–118.

(232) ——. 1929. Weitere Beiträge zur Kritik und zum Ausbau phytoserologischer Methodik. *Planta*, 7: 759–814.

(233) ——. 1931. Die serologische Analyse von Proteinkomplexen (Protenomen) als Methode der biologischen Verwandtschaftsforschung. *Ber. Deut. Bot. Ges.*, 49: (76)–(78).

(234) ——. 1932. Zur Frage der Antigen-Antikörper Reaktionen bei Pflanzen. *Ber. Deut. Bot. Ges.*, 50(1): Generalversammlh.: 100–106.

(235) Moritz, O. 1932. Prinzipien und Beispiele der Andwendung phytoserologischer Methodik. *Planta*, 15: 647–696.

(236) ——. 1933. Serologische Untersuchungen an Getreidebastarden. *Ber. Deut. Bot. Ges.*, 51(1), Generalversammlh: 52–57.

(237) ——. 1934. Die botanische Serologie. *Beitr. Biol. Pfl.*, 22.: 51–90.

(238) ——. 1934. Über serologische Verwandtschaftsforschung. *Der Züchter*, 6: 217–221.

(239) ——, and H. vom Berg. 1931. Serologische Studien über das Linswickenproblem. *Biol. Ctbl.*, 51: 290–307.

(240) Muellers, J. H., and J. Tomcsik. 1924. The chemical nature of residue antigen prepared from yeast. *Jour. Exp. Med.*, 40: 343–352.

(241) Müller, F. 1899. Beiträge zur Toxikologie des Ricins. *Arch. Exp. Path. Pharm.*, 42: 302–322.

(242) Müller, H. 1932. Phytoserologische Untersuchungen über die systematische Stellung der Apetalen. Diss. *Berlin.*

(243) Müller, W. 1911. Studien über die Giftigkeit der Rizinussamen und den Nachweis des Giftes. *Deut. Tierärztl. Wschr.*, 19: 433–436, 449–453, 463–467.

(244) Mulvania, M. 1925. Studies on the nature of the virus of tobacco mosaic. *Phytopath.*, 16: 853–871.

(245) Nahmmacher, E. 1929. Über die Brauchbarkeit künstlicher Immunsera für die Serodiagnostik in der botanischen Verwandtschaftsforschung. *Beitr. Biol. Pfl.*, 17: 1–44.

(246) Nakahara, T. 1910. Über die hämolytische Wirkung des Chlorophylls. Diss. *Osaka.* (Abst. in *Ztschr. Immunf.* Ref., 1910: 474).

(247) Nakayama, H. 1906. Impfversuche mit *Aktinomyces asteroides* Eppinger an Meerschweinchen. Zugleich ein Beitrag zur Frage der Überempfindlichkeit. *Arch. f. Hyg.*, 58: 207–312.

(248) Nay, W. 1927. Serodiagnostische Verwandtschaftsforschungen innerhalb der Rosales, Myrtiflorae und Umbelliflorae. *Beitr. Biol. Pfl.*, 15: 147–179.

(249) Nelson, C. I. 1926. The intracellular proteins of bacteria. I. Globulins. *Jour. Infect. Dis.*, 38: 371–377.

(250) ——, and J. M. Birkeland. 1929. A serological ranking of some wheat hybrids as an aid in selecting for certain genetic characters. *Jour. Agr. Res.*, 38: 169–181.

(251) ——, and M. Dworak. 1926. Studies on the nature of wilt resistance in flax. *N. Dak. Agr. Exp. Sta. Bull.*, 202: 3–30.

(252) Nelson, C. I., and A. T. Henrici. 1922. Immunologic studies with actinomycetes with special reference to the acid-fast species. *Proc. Soc. Exp. Biol. Med.*, 19: 351–352.

(253) Neuberg and Rosenberg. 1907. *Berl. Klin. Wschr.*, 44: 54.
Neuberg. 1908. *Biochem. Ztschr.*, 11: 400.
Both in: Mendel, L. B. 1909. Observations on vegetable haemagglutinins. *Arch. di Fisiol.*, 7: 168–177.

(254) Neuhoff, W., and H. Ziegenspeck. 1926. Morphologisch-serologische Bearbeitung des Systems der Basidiomyceten. *Bot. Arch.*, 16: 296–359.

(255) Nicoletti, F. 1934. Ricerche sulla capacità antigene della combinazione morfina-proteina. *Riv. Patol. Sper.* N.S., 1: 251–260.

(256) Nitzescu, J. J. 1914. Die Schützfermente gegen das Maiseiweiss (Zeine) im Blut der Pellagrösen. *Deut. Med. Wschr.*, 40: 1614–1615.

(257) Nuttall, G. H. F. 1901. The new biological test for blood in relation to zoological classification. *Proc. Roy. Soc. London*, 69: 150–153.

(258) ——. 1901. A further note on the biological test for blood and its importance in zoological classification. *Brit. Med. Jour.*, 2: 669.

(259) ——. 1902. Further observations upon the biological test for blood. *Proc. Cambr. Philos. Soc.*, 11: 334–336.

(260) ——. 1904. Blood immunity and blood relationship, a demonstration of certain blood relationships amongst animals by means of the precipitin test for blood. Cambridge, Univ. Press.

(261) Obermayer, F., and E. Pick. 1904. Beiträge zur Kenntnis der Präzipitinbildung. Über den Begriff der Art- und Zustandspezifität (originäre und konstitutive Gruppierung) und die Beeinflussung der chemischen Eigenart des Tierkörpers. *Wien. Klin. Wschr.*, 17: 265–267.

(262) ——, and ——. 1906. Über die chemischen Grundlagen der Arteigenschaften der Eiweisskörper. Bildung von Immunpräzipitinen durch chemische veränderte Eiweisskörper. *Wien. Klin. Wschr.*, 19: 327–334.

(263) Osborne, T. B. 1924. The Vegetable Proteins. Ed. 2. pp. 118–121. *London*, Longmans, Green & Co.

(264) ——, L. B. Mendel, and I. F. Harris. 1905. A study of the proteins of the castor bean with special reference to the isolation of ricin. *Am. Jour. Physiol.*, 14: 259–286.

(265) Ostromyslensky, I. I. 1915. Researches in the province of toxins and antitoxins. (Transl. title). *Jour. Russ. Phys. Chem. Soc.*, 47: 263–317.

(266) Ottensooser, F. 1927. Serologische Differenzierung von Hefen. (From a lecture at 89th Versl. Deut. Naturf. u. Ärzte in Düsseld. 1926.) *Bot. Arch.*, 17: 147–157.

(267) Ottolenghi, D. 1902. Sulla ricerca del tuorlo d'ovo nelle paste alimentari e su alcune applicazioni delle precipitine in bromatologia. *Atti R. Accad. Fisiocrit. Siena*, Ser. 4, 14: 285–290.

(268) ——. 1903. Siero precipitante per la segale cornuta. *Atti R. Accad. Fisiocrit. Siena*, Ser. 4, 15: 253–254.

(269) Pachorukow, D. 1888. Über Sapotoxin. *Arb. Pharm. Inst. Dorpat*, 1: 1–56.

(270) Peckham, J. F. 1925. Study of yeasts from human sources. *Jour. Infect. Dis.*, 37: 53–61.

(271) Perles, M. 1889. Beiträge zur Kenntnis der Wirkungen des Solanins und Solanidins. *Arch. Exp. Pathol.*, 26: 88–132.

(272) Pick, E. P. 1912. Biochemie der Antigene, mit besonderer Berücksichtigung der chemischen Grundlagen der Antigenspezifität. B. Pflanzliche toxische Antigene (Phytotoxine). In: Kolle and von Wassermann, Handb. der pathogenen Mikroorgan., 1: 792–819.

(273) Pohl, J. 1900. Über Blutimmunität. *Arch. Intern. Pharm. Therap.*, 7: 1–9.

(274) ——. 1901. Über Blutimmunität. *Arch. Intern. Pharm. Therap.*, 8: 437–448.

(275) Porges, O. 1909. Über Opsonine für Stärke. *Ztschr. Immunf.*, 2: 4–12.

(276) Pozerski, E. 1908. Anaphylaxie du cabaye pour la papaïne. *C. R. Soc. Biol.*, 64: 631–632.

(277) ——. 1908. Sur la présence d'anticorps spécifiques dans le sérum de lapins préparés contre la papaïne. *C. R. Soc. Biol.*, 64: 896–898.

(278) Preuss, A. 1917. Sero-diagnostische Untersuchungen über die Verwandtschaften innerhalb der Pflanzengruppe der Parietales. *Beitr. Biol. Pfl.*, 13: 459–499.

(279) Purdy, H. A. 1928. Immunologic reactions with tobacco mosaic virus. *Proc. Soc. Exp. Biol. Med.*, 25: 702–703.

(280) ——. 1929. Immunologic reactions with tobacco mosaic virus. *Jour. Exp. Med.*, 49: 919–935.

(281) (Purdy-) Beale, H. A. 1931. Specificity of the precipitin reaction in tobacco mosaic disease. *Contr. Boyce Thompson Inst.*, 3: 529–539.

(282) (Purdy-) Beale, H. A. 1933. Serologic reaction as a means of determining the concentration of tobacco mosaic virus. *Phytopath.*, 23: 4.

(283) ——. 1934. The serum reactions as an aid in the study of the filterable viruses of plants. *Contr. Boyce Thompson Inst.*, 6: 407–435.

(284) Rabe, F. 1911. Beiträge zur Toxikologie des Knollenblätterschwammes. *Ztschr. Exp. Path. Therap.*, 9: 352–364.

(285) Radzwillowicz, R. 1888. Über Cytisin. *Arb. Pharm. Inst. Dorpat.* 2: 56–101.

(286) Raeder, F. 1914. Sero-diagnostische Untersuchungen über strittige Verwandtschaftsverhältnisse innerhalb der Dikotylen. *Bot. Arch.*, 7: 9–40.

(287) Raubitschek, H. 1909. Zur Kenntnis der Immunantiphytalbumine. *Wien. Klin. Wschr.*, 22: 1752–1753.

(288) ——. 1911. Hämagglutinine pflanzlicher Provenienz und ihre Antikörper. Kraus u. Levaditi, Hdb. Tech. u. Meth. Immunf. I. Ergänzbd., 625–630.

(289) ——, and M. Wilenko. 1910. Über den Zusammenhang der hämagglutinierenden und präzipitierenden Fähigkeit pflanzlicher Antigene. *Ztschr. Immunf.*, 5: 446–457.

(290) Relander, L. K. 1908. Kann man mit Präzipitinreaktion Samen von verschiedenen Pflanzenarten und Abarten voneinander unterscheiden? *Cbl. Bakt.* II, 20: 518–522.

(291) ——. 1911. Studien über die Verwendbarkeit der Präzipitinreaktion in der Samenprüfung. Diss. Helsinfors, Druck. Sana, Helsingfors. *Abh. Agrikulwiss. Ges. in Finland* 1911, Heft 1. 85 pp.

(292) Reuter, K. 1926. Die Phylogenie der Parietales. *Bot. Arch.*, 16: 118–217.

(293) Richet, C. 1909. Études sur la crépitine (Toxine de *Hura crepitans*). *Ann. Inst. Past.*, 23: 745–800.

(294) Rives, L. 1923. Emploi du séro-diagnostic pour la détermination de "l'affinité" des hybrides de vigne. *Rev. Vitic.*, 58: 300–302.

(295) ——. 1923. Sur l'emploi du sérodiagnoste pour la détermination del'affinitie au greffage des hybrides de vigne. *Prog. Agr. et Vit.*, 79: 118–119.

(296) Roederer, H. 1930. Die Phylogenie des Rosales-Astes. *Bot. Arch.*, 29: 330–436.

(297) Rosenau, M. J., and J. F. Anderson. 1907. Studies upon hypersusceptibility and immunity. *Hyg. Lab. Bull.* 36. *U. S. Publ. Health and Marine Hosp. Serv.* 67 pp.

(298) Rosenau, M. J., and J. F. Anderson. 1907. Further studies upon hypersusceptibility and immunity. *Jour. Med. Res.*, 6: 381–418.

(299) ——, and ——. 1908. Further studies upon anaphylaxis. *Hyg. Lab. Bull.* 45, *U. S. Publ. Health and Marine Hosp. Serv.*

(300) Rosenblat-Lichtenstein, S. 1912. Über die Differenzierung von Algen mit Hilfe spezifischer Agglutinine. I. Mitt. *Arch. f. Physiol.*, 1912: 415–420.

(301) ——. 1913. Agglutination bei Algen. II. Mitteilung. Beziehung des Stoffwechsels der Zelle zu ihrem agglutinatorischen Verhalten. *Arch. f. Physiol.*, 1913: 95–99.

(302) Ruff, O. 1930. Zur Phylogenie des Columniferen-Astes der Dikotylen. *Bot. Arch.*, 31: 1–140.

(303) Sachs, H. 1930. Serologische Funktionen von Lipoiden. *Forsch. u. Fortschr.*, 6: 82–83.

(304) Saltzmann, B. 1924. Ergänzende sero-diagnostische Untersuchungen. *Bot. Arch.*, 8: 3–36.

(305) Sanfelice, F. 1896. Über die Immunität gegen Blastomyceten. *Ctlbl. Bakt.* I, 20: 219–222.

(306) ——. 1902. Die Antikörper des Blutserums mit Blastomyceten behandelter Tiere. *Ctbl. Bakt.* I, 32: 360–365.

(307) Sartory, A. 1920. Champignons parasites de l'Homme et des Animaux. Arsant, *St. Nicolas du Port.* p. 574.

(308) Sasse, F. 1928. Untersuchungen über Pflanzenkünstsera nach Mez, und ihre Verwendbarkeit für die botanische Verwandtschaftsforschung. *Beitr. Biol. Pfl.*, 16: 351–404.

(308a) Sauer, M. E. 1935. Correlation of immunologic and physiologic types of *Euglena gracilis* Klebs. *Arch. Protistenk.*, 85: 412–415.

(308b) ——. 1936. The chlorolytic action of serum. *Plant Physiol.*, 11: 159–166.

(309) Sauli, J. O. 1911. Über den Nachweis von verschiedenartigem pflanzlichen Eiweiss durch Konglutination. *Ztschr. Immunf.* I, 9: 359–368.

(310) Sayer, A. 1921. Specific treatment of Dermatitis venenata (*Rhus toxicodendron*). *Med. Rec.*, 100: 717–720.

(311) Schenk, D. 1916. Die Anwendbarkeit des serologischen Verfahrens bei der Prüfung pharmazeutischer Eiweisspräparate. Versuche mit Tanninalbuminaten und Eisenalbuminat. Ein weiterer Beitrag zur Kenntnis der Präzipitine, besonders der Hitzealkalipräzipitine. *Apothekerzeit.*, 31: 426–427, 431–432, 435–436.

(312) Schenk, D., and H. Burmeister. 1915. Serologischer Nachweis von Kartoffel und Kartoffelzubereitungen. Ein Beitrag zur Kenntnis der fällenden Sera. *Ztschr. Untersuch. Nähr.-u. Genüssmittel.*, 30: 325–332.

(313) ——, and ——. 1915. Serologischer Nachweis von Kartoffeln und Kartoffelpräparaten. *Apothekerzeit.*, 30: 234.

(314) Schern, K. 1910. Experimentelle Beiträge zur praktischen Verwertbarkeit der Anaphylaxie. *Arch. Wiss. Prakt. Tierheilk.*, 36: 590–610.

(315) ——. 1911. Über die Verwendung der Anaphylaxie zum Nachweis von Verfälschung der Futtermittel. *Berl. Tierärztl. Wschr.*, 27: 113–115.

(316) Schmidt, W. 1926. Herkunftsermittlung bei Kiefernsaatgut. *Forstl. Wschr. Silva*, 14: 233–239.

(317) Schneider, E. C. 1912. The haemagglutinating and precipitating properties of the bean (*Phaseolus*). *Jour. Biol. Chem.*, 11: 47–59.

(318) Scholz, P. 1930. Versuch zur Klärung der systematischen Stellung der Loasaceen auf Grund phytoserologische Untersuchungen. Diss. Berlin, Druck. Noske, *Leipzig.*

(319) Schussnig, B. 1926. Kritisches Referat über: "Steinecke, F. Der Stammbaum der Algen nach sero-diagnostischen Untersuchungen dargestellt. *Bot. Arch.*, 10 (1925): 82–205." *Ztschr. Induks. Abstamm.-u. Vererbsl.*, 40: 240–252.

(320) Schütze, A. 1901. Weitere Beiträge zum Nachweis verschiedener Eiweissarten auf biologischem Wege. *Ztschr. Hyg. Infekkr.*, 38: 487–494.

(321) ——. 1901. Über Isopräcipitine (Isolactoserum). *Verh. Ges. Charité Ärzte*, 7: 109–111.

(322) ——. 1902. Über weitere Anwendung der Präzipitine. *Deut. Med. Wschr.*, 28: 804–806.

(323) ——. 1903. Zur Frage der Differenzierung einzelner Hefearten mittels der Agglutinine. *Ztschr. Hyg. Infekkr.*, 44: 423–427.

(324) ——. 1911. Zur Frage der Differenzierung einzelner Hefearten auf dem Wege der Komplementbindung. *Ztschr. Immunf.* I, 8: 611–615.

(325) Schwandt, K. 1930. Beiträge zur Kenntnis der systematischen Stellung der Gattung *Parnassia* auf Grund phytoserologischer Untersuchungen. Diss. Berlin, Druck. Noske, *Leipzig.*

(326) Sherwood, N. P. 1926. A study of the antigenic properties of chlorophyll. *Abstr. Bacteriol.*, 9: 22–23.

(327) Silberschmidt, K. 1931. Studien zum Nachweis von Antikörpern in Pflanzen. I. *Planta*, 13: 114–168.

(328) ——. 1933. Studien zum Nachweis von Antikörpern in Pflanzen. II. Beitr. zur Frage der Resistenz und Immunität von Pflanzen gegenüber dem infizierenden Agens der Viruskrankheiten. *Beitr. Biol. Pfl.*, 20: 105–178.

(329) Skchiwan. 1899. Contribution à l'étude du sort des levures dans l'organisme. *Ann. Inst. Past.*, 13: 770–777.

(330) Slatmann, W. 1928. Phytoserologische Untersuchungen. II. Vergleichende Untersuchungen über die Kapillarmethode mit Phosphat, die Kapillarmethode ohne Phosphat und die Mez'sche Präzipitationsreaktion. *Planta*, 6: 277–314.

(331) Spooner, E. T. C., and F. C. Bawden. 1935. Experiments on the serological reactions of the potato virus "X". *Brit. Jour. Exp. Path.*, 16: 218–230.

(332) Stanley, W. M. 1935. Isolation of a crystalline protein possessing the properties of tobacco-mosaic virus. *Science*, 81: 644–645.

(332a) ——. 1936. Chemical studies on the virus of tobacco mosaic. VI. The isolation from diseased Turkish tobacco plants of a crystalline protein possessing the properties of tobacco-mosaic virus. *Phytopath.*, 26: 305–320.

(332b) ——. 1936. The inactivation of crystalline tobacco-mosaic virus protein. *Science*, 83: 626–627.

(333) Steinecke, F. 1925. Der Stammbaum der Algen nach sero-diagnostischen Untersuchungen dargestellt. *Bot. Arch.*, 10: 82–205.

(334) ——. 1925. Die Bedeutung der Serodiagnostik für die Verwandtschaftsforschung. *Naturwiss.*, 13: 853–856.

(335) Stepputat, W. 1929. Serodiagnostische Untersuchungen über die Phylogenie der Laubmoose. *Bot. Arch.*, 24: 354–390.

(336) Stillmark, H. 1889. Über Ricin. *Arb. Pharm. Inst. Dorpat*, 3: 59–151.

(337) Stolley, E. 1925. Die Psilophyten. *Jahresber. Niedersächs. Geol. Ver.*, 18: 39– . (Discussion by Mez in *Bot. Echo*, 1925: 67–69.)

(338) ——. 1925. Zur Kritik der Königsberger Serodiagnostik. *Jahresber. Niedersächs. Geol. Ver.*, 19: (1)–(7).

(339) ——. 1927. Das Ende der Königsberger Serodiagnostik. *Jahresber. Niedersächs. Geol. Ver.*, 20: 97–110.

(339a) Straus, H. W. 1931. Artificial sensitization of infants to poison ivy. *Jour. Allergy*, 2: 137–144.

(340) Strickler, A. 1918. The treatment of Dermatitis venenata by vegetable toxins. *Jour. Cutan. Dis.*, 36: 327–331.

(341) ——. 1921. The toxin treatment of Dermatitis venenata. *Jour. Am. Med. Assn.*, 77: 910–912.

(342) ——. 1923. The value of the toxin (antigen) of *Rhus toxicodendron* and *Rhus venenata*. *Jour. Am. Med. Assn.*, 80: 1588–1590.

(343) Sturm, K. 1910. Monographische Studien über *Adoxa moschatellina* L. *Vierteljahrsschr. Naturforsch. Ges. Zürich*, 55: 391–462.

(344) Sugg, J. Y., and J. M. Neill. 1929. Studies on immunological relationships among the pneumococci. III. Relationship between a variety of *Saccharomyces cerevisiae* and the type II variety of *Diplococcus pneumoniae* (pneumococcus). *Jour. Exp. Med.*, 49: 183–193.

(345) Takemura, M. 1910. Sind Methylenblau und Hämatoxylin Antigene? *Ztschr. Immunf.*, 5: 697–699.

(346) Thöni, J. 1910. Beitrag zur Frage der Differenzierung von Pflanzenarten mittelst des biologischen Verfahrens (Komplementbindungsmethode). *Mitt. Geb. Lebensmittelunters. u. Hyg.*, 1: 175–187.

(347) ——, and A. C. Thaysen. 1914. Versuche zur Herstellung von spezifisch wirkenden Getreideantiseris für den Nachweis von Mehlverfälschung. *Ztschr. Immunf.*, I, 23: 83–107.

(348) Tomcsik, J., and T. J. Kurotchkin. 1928. On the rôle of carbohydrate haptens in bacterial anaphylaxis. *Jour. Exp. Med.*, 47: 379–388.

(349) Tscharnotsky, A. 1910. Anaphylaxie. Diss. *Moscow*. (Abst. *Ztschr. Immunf.* Ref., 1910: 378.)

(350) Tufanow, N. 1888. Über Cyclamin. *Arb. Pharm. Inst. Dorpat*, 1: 100–145.

(351) Uhlenhuth, P., and Haendel. 1910. Untersuchungen über die praktische Verwertbarkeit der Anaphylaxie zur Erkennung und Unterscheidung verschiedener Eiweissarten. *Ztschr. Immunf.*, I, 4: 761–816.

(352) ——, (and Jung). 1905. Über ein Ausflockungsphänomen in künstlichen Öl-Emulsionen durch normaler und vorbehandelter Tiere. *Vereinsbeil. Deut. Med. Wschr.*, 31: 564.

(353) ——, and O. Weidanz. 1909. Technik und Methodik des biologischen Eiweissdifferenzierungsverfahrens (Präzipitinmethode) mit

besonderer Berücksichtigung der forensischen Blut- und Fleischuntersuchung. *In*: Kraus and Levaditi, Handb. der Tech. u. Meth. der Immunf., 2: 721–833.

(354) Uhlenhuth, P., and O. Weidanz. 1909. Praktische Anleitung zur Ausführung des biologischen Eiweissdifferenzierungsverfahrens mit besonderer Berücksichtigung des forensischen Blut- und Fleischuntersuchung sowie der Gewinnung präzipitierender Sera. *Jena*, G. Fischer. 246 pp.

(355) Vavilov, N. I. 1914. Immunity to fungous diseases as a physiological test in genetics and systematics, exemplified in cereals. *Jour. Genet.*, 4: 49–65.

(356) Verplancke, G. 1935. Étude des propriétés des virus causant les maladies de dégénérescence de la betterave. IV. Reactions immunologiques du virus de la mosaïque de la betterave. *Sucrerie Belge*, 54: 162–168.

(356a) ——, and L. Asaert. 1934. Immunologische reakt'es met plantenvirus. *Natuurw. Tijdschr.*, 16: 69–74.

(357) Wächter, W. 1927. Berlin gegen Königsberg. Ein wissenschaftliches Duell. *Apothekerzeit.*, 42: 839–842.

(358) ——. 1927. Königsberg Getöse. Eine freundliche Abwehr. *Apothekerzeit.*, 42: 1322–1324.

(359) Wartenberg, F. 1930. Über Organspezifität und Artspezifität des pflanzlichen Eiweisses und ihre Bedeutung für die botanische Stammesforschung. Diss. Berlin, Druck. Denter and Nicolas, *Berlin*.

(360) Wechselmann. 1909. Über Satinholzdermatitis, eine Anaphylaxie der Haut. *Deut. Med. Wschr.*, 35: 1389–1391.

(361) Wells, H. G. 1908. Studies on the chemistry of anaphylaxis. *Jour. Infect. Dis.*, 5: 449–483.

(362) ——. 1925. The Chemical Aspects of Immunity. Chem. Catal. Co., *New York*, *N. Y.*

(363) ——. 1927. Immunology as a Branch of Chemistry. 17 pp. Columbia Univ. Press, *N. Y.*

(364) ——, J. H. Lewis, and D. B. Jones. 1927. Immunologic reactions of the globulins from the seeds of leguminous plants. The biologic reactions of the vegetable proteins IX. *Jour. Infect. Dis.*, 40: 326–342.

(365) ——, and T. B. Osborne. 1911. The biological reactions of the vegetable proteins. I. Anaphylaxis. *Jour. Infect. Dis.*, 8: 66–124.

(366) ——, and ——. 1913. Is the specificity of the anaphylaxis reaction dependent on the chemical constitution of the proteins or on their biological relations? The biological reactions of the vegetable proteins II. *Jour. Infect. Dis.*, 12: 341–358.

(367) Wells, H. G., and T. B. Osborne. 1914. The anaphylactogenic activity of some vegetable proteins. The biological reactions of the vegetable proteins V. *Jour. Infect. Dis.*, 14: 377–384.

(368) ——, and ——. 1915. The anaphylaxis reactions with so-called proteoses of various seeds. The biologic reactions of the vegetable proteins VI. *Jour. Infect. Dis.*, 17: 259–275.

(369) ——, and ——. 1916. Anaphylaxis reactions between proteins from seeds of different genera of plants. The biologic reactions of the vegetable proteins VII. *Jour. Infect. Dis.*, 19: 183–193.

(370) Wendelstadt, and T. Fellmer. 1910. Beiträge zur Kenntnis der Immunisierung durch Pflanzeneiweiss. *Ztschr. Immunf.*, I, 8: 43–57.

(371) Wermund, R. 1928. Untersuchungen über die Brauchbarkeit der Serodiagnostik für die botanische Verwandtschaftsforschung mit besonderer Berücksichtigung der Reihe der Rhoeadales, sowohl unter Anwendung der Präzipitationsmethode, als auch der Konglutinationsmethode nach Mez. *Beitr. Biol. Pfl.*, 16: 39–80.

(372) Wettstein, R. von. 1924. Handbuch der systematischen Botanik. Ed. 3. *Leipzig* and *Wien*, Druck. Deuticke. pp. 34, 413.

(373) ——. 1925. Die Bedeutung der sero-diagnostischen Methode für die phylogenetisch-systematische Forschung. *Ztschr. Induks. Abstamm.- und Vererbl.*, 36: 438–445.

(374) White, B., and O. T. Avery. 1913. Some immunity reactions of edestin. The biological reactions of the vegetable proteins III. *Jour. Infect. Dis.*, 13: 103–123.

(375) Wienhaus, O. 1909. Zur Biochemie des Phasins. *Biochem. Ztschr.*, 18: 228–260.

(376) Wilcox, H. W., and G. K. K. Link. 1935 (1934). Serically active (haptenic) carbohydrates of genotypes of *Neurospora tetrasperma* and *N. sitophila*. (Abst.) *Phytopath.*, 25: 39.

(377) Wilenko, M. 1910. Über das Präcipitationsvermögen pflanzlicher Eiweissstoffe. *Ztschr. Immunf.*, 5: 91–104.

(378) Wilke, H. 1929. Die Phylogenie der Rhodophyceae. *Bot. Arch.*, 26: 1–85.

(379) Wilkoewitz, K. 1929. Über die Serologie und Morphologie des Farnastes. *Bot. Arch.*, 23: 445–531.

(380) ——, and H. Ziegenspeck. 1928. Die verschiedenen Generationen und Jugend- und Altersformen in ihrer Einwirkung auf den Ausfall der Präcipitinreaktionen. *Bot. Arch.*, 22: 229–244.

(381) Williams, C. M., and J. A. MacGregor. 1924. Treatment of ivy poisoning by *Rhus* tincture and antigen. *Arch. Derm. and Syph.*, 10: 515–517.

(382) Wodehouse, R. P. 1917. Immunochemical studies of the plant proteins: proteins of the wheat seed and other cereals. Study IX *Am. Jour. Bot.*, 4: 417–429.

(383) Worsdell, W. 1922. Sero-diagnostische Untersuchungen über die Verwandtschaftsverhältnisse der Monocotyledonen. *Bot. Arch.*, 2: 177–206.

(384) Zade, A. 1912. Die Verwendbarkeit der Präzipitinreaktion in der Samenprüfung. *Fühlings Landw. Zeit.*, 61: 807–810.

(385) ——. 1914. Serologische Studien an Leguminosen und Gramineen. *Ztschr. f. Pflanzenzücht.*, 2: 101–151.

(386) Zalkowitz, J. 1932. Phytoserologische Verwandtschaftsuntersuchungen über die Sarraceniaceae, Nepenthaceae und Droseraceae und ihre Stellung im System. Diss. Berlin, Druck. Herper, *Berlin.*

(387) Zarnack, H-G. 1927. Untersuchungen über die Brauchbarkeit der Serodiagnostik für die botanische Verwandtschaftsforschung, erläutert an der Reihe der Ranales. *Beitr. Biol. Pfl.*, 15: 180–227.

(388) Ziegenspeck, H. 1925. Der serologische Stammbaum des Pflanzenreiches und die Phytopalaeontologie. *Bot. Arch.*, 9: 37–48.

(389) ——. 1925. Die Stelärtheorie und der serologische Stammbaum. *Bot. Arch.*, 10: 4–10.

(390) ——. 1926. Kritisches und Strittiges. Eine experimentelle Antwort auf R. Wettstein: Die Bedeutung der sero-diagnostischen Methode für die phylogenetisch-systematische Forschung. *Bot. Arch.*, 16: 218–268.

(391) ——. 1927. Die systematische Bedeutung der Haploid-Generationen verglichen mit den Ergebnissen der Sero-diagnostik. *Bot. Arch.*, 17: 212–312.

(392) Zimmermann, W. 1928. Eiweissverwandtschaft und Stammesverwandtschaft in der botanischen Serologie. *Süddeutsche Apotheker-Zeitung*, 68: 196.

DETERMINATION OF LIMB-AXES

By F. H. SWETT

Department of Anatomy, Duke University School of Medicine

INTRODUCTION

THE various problems of development and growth ultimately may be shown to have similar answers and, although speculation concerning them is of consuming interest, we are rather completely occupied at present with preliminary studies on the many phases of the subject and the end is far from being in sight. Differentiation of tissues, organs and organ systems is being investigated from many angles, a small portion of one of which has been chosen for discussion. The restricted field of polarity fixation in the limb-axes has been selected chiefly because of a peculiar concentration of personal interest. Direct reference to the problems of causality and of terminology, discussed in part by Harrison ('33), is omitted from consideration here. It is proposed merely to set forth a simplified review of some of the more firmly established observations together with suggestions for future investigation.

Most of the experimental work upon limb development has been carried out upon embryos of various species of amphibia although the chick has been used to some extent. It happens that the phase to be discussed has involved more particularly the urodele embryo and has been a direct outgrowth of the pioneer studies which are too well known to need comment at this time.

THE LIMB RUDIMENT AND ITS AXES

At the stage of development (Fig. 1) most used for the earlier experiments upon the limb, the cells whose prospective significance lies in that direction are situated (Harrison, '18) in a flattened disc just ventral to the pronephros and cover an area roughly corresponding to the width of three somites (3, 4 and 5). For the purpose of the present discussion not the least important results were derived from Harrison's ('21) experiments which indicated that axial differentiation in the limb was inherent in the intimate protoplasmic structure of the rudiment. Subsequent experiments have provided no evidence to the contrary and the stereodiagrams presented at that time to show the "hypothetical progressive differentiation of the structural units" (Fig. 136, p. 89) may be reproduced here (Fig. 2) as a framework upon which to hang the work to be described. The first diagram represents an isotropic condition with no axial polarization, the second has one axis polarized, the third has two, the fourth and fifth have three—the last two figures representing a mirror imaged pair. The condition of isotropy (Fig. 2, *1*) has not been demonstrated to obtain in any normally developing limb rudiment. If it exists at all, it must do so most fleetingly and in a stage of development somewhat earlier than is convenient to use for experimental removal of the anlage.

This is indicated by Detwiler's ('33) observation that limb-forming cells, transplanted from embryos

with large to medium sized yolk-plugs, already have a polarized anteroposterior axis. Milojević's ('23, '24) studies indicated that conditions may be somewhat different in regenerating limb blastemas and that they, in early stages, may be composed of cells which are quite indifferent so far as polarization is concerned. However, similar experiments carried out by Lodyženskaja ('28, '29) upon limb regeneration in the axolotl do not support those obtained by Milojević upon *Triton*.

The conditions of these experiments, especially the retrograde changes undergone by some of these buds after transplantation, make it doubtful whether the

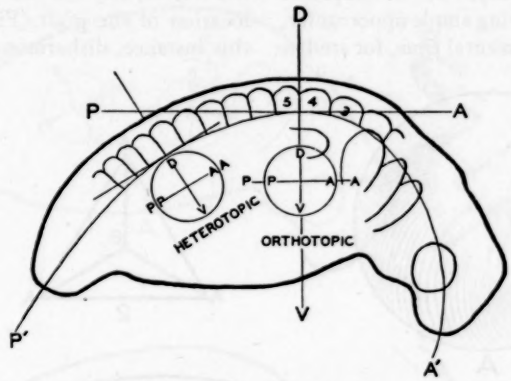

FIG. 1. DIAGRAM OF A. PUNCTATUM EMBRYO IN STAGE 29 (MODIFIED FROM HARRISON, '25, FIG. 10, P. 483)
The circles represent limb rudiments, in normal location (orthotopic) and in a flank position (heterotopic), after transplantation. The letters within the circles represent cardinal points of the limb-axes; A = anterior, P = posterior, D = dorsal, V = ventral. Similar letters outside the circles represent the axes of the embryo body – relative to the line A′ – P′ drawn to correspond to the body curvature. The three myotomes of the limb area are numbered – 3, 4, 5. Magn. approx. × 16.

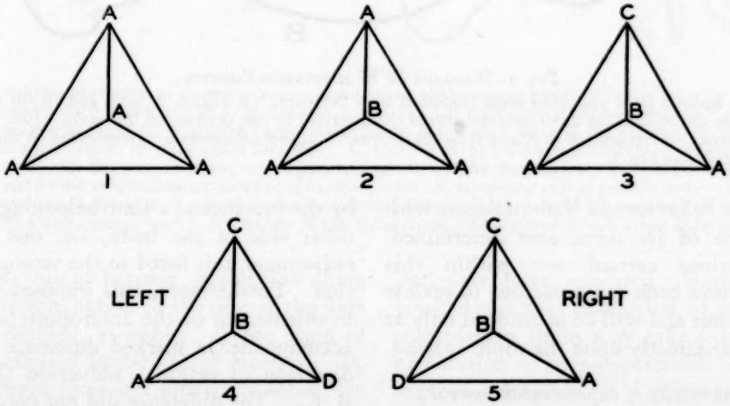

FIG. 2. DIAGRAMS TO SHOW HYPOTHETICAL PROGRESSIVE DIFFERENTIATION OF THE STRUCTURAL UNITS
(1) Condition of isotropy; (2) polarization with reference to one axis; (3) bilateral symmetry (two axes differentiated); (4 and 5) condition of complete asymmetry (three axes differentiated), giving right and left enantiomorphs (from Harrison, '21, Fig. 136, p. 89).

results with regenerating blastemas should be compared directly with those from embryonic rudiments.

THE ANTEROPOSTERIOR AXIS

In *Amblystoma punctatum* the condition of a single polarized axis (Fig. 2, *2*) persists through several days of development (Fig. 3) thereby giving ample opportunity, in point of developmental time, for studies upon the behavior of a limb rudiment with only one of its three axes determined. Observations carried out within this period have been too numerous to review at this time and will be mentioned only as they bear directly upon the topic at hand.

Some results of experimental reversal

Harrison's ('21, '25) experiments (Fig. 4) showed very clearly that normal orientation of this anteroposterior axis with relation to the body wall of the embryo (A) resulted in the production of a harmonic limb (C); also that reversal of this axis at operation (D) produced a disharmonic limb (F). The orientation, whether normal or abnormal, of the other two axes of the limb made no difference in the results, nor did the side of origin or location of the graft (Fig. 4, A.D.). In this instance, disharmony was occasioned by the presence of a limb belonging to the other side of the body, i.e. one whose radio-ulnar axis faced in the wrong direction. Furthermore, this imposed change in orientation of the anteroposterior axis accomplished a marked difference in the direction of original adduction (Fig. 4, B, E). The difference did not correspond exactly to the 180° disorientation of the embryonic axis but was often as much as 120°. Operative reversal of no other axis,

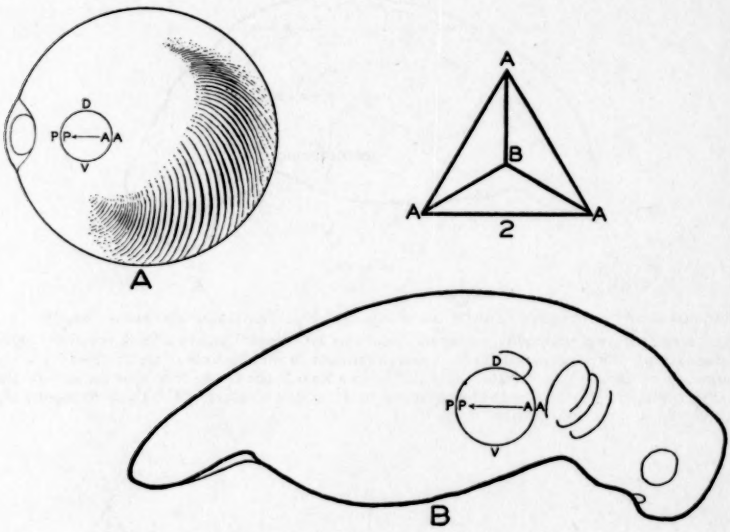

FIG. 3. DIAGRAMS OF A. PUNCTATUM EMBRYOS

(A) In medium sized yolk-plug stage (modified from Detwiler, '33, Fig. 2, p. 407), and (B) in stage 32; to show the duration of the developmental period characterized by one determined limb-axis. This axis, the anteroposterior, is represented in A and B by the arrows. The stereodiagram *2* corresponding to this period is reproduced from Fig. 2.

even after it becomes determined, brings about such a marked alteration. This question of the direction of limb growth, in the normal embryo as well as after transplantation, has been fully discussed by Harrison ('25). It is of interest that such an important feature of development as this should become established along with determination of the first of the axes and probably, therefore, at the time of segregation of limb-forming material. If, or perhaps more optimistically when, we secure our isotropic limb anlage the degree of correspondence between these two characters should be investigated.

Determination of the anteroposterior axis

More or less as a by-product of experiments carried out on embryos belonging to the period of development under consideration, certain interesting suggestions concerning fixation of the anteroposterior limb-axis have appeared. Harrison has pointed out that regulation of posture in transplanted limbs may take place either by rotation or by reduplication with subsequent resorption of a primary, potentially disharmonic bud. Nicholas ('24) has investigated the question of rotational recovery of posture, and the phenomenon

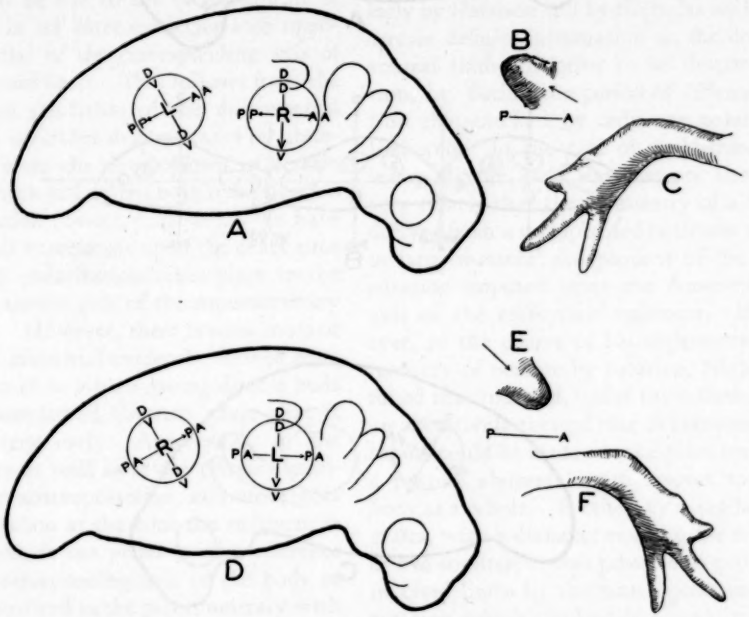

FIGURE 4

A. Diagram of embryo to show harmonic combinations of the antero-posterior limb-axis with the embryo body, using a right rudiment (R) as orthotopic graft and a left rudiment (L) heterotopically. B. Showing the posterodorsal direction of growth (when projected on the median plane of the embryo) of the limb bud when the embryo-graft combination is harmonic. C. Outline of the harmonic primary limb which arises from such a graft. D. Diagram to show, in comparison with A, a right (heterotopic) and left (orthotopic) rudiment grafted with anteroposterior axes out of harmony with corresponding axes of embryo body. E. Showing the anteroventral direction of growth (when projected on the median plane of the embryo) of the limb bud from such a disharmonic graft. F. Outline of the disharmonic primary limb which arises from such a graft.

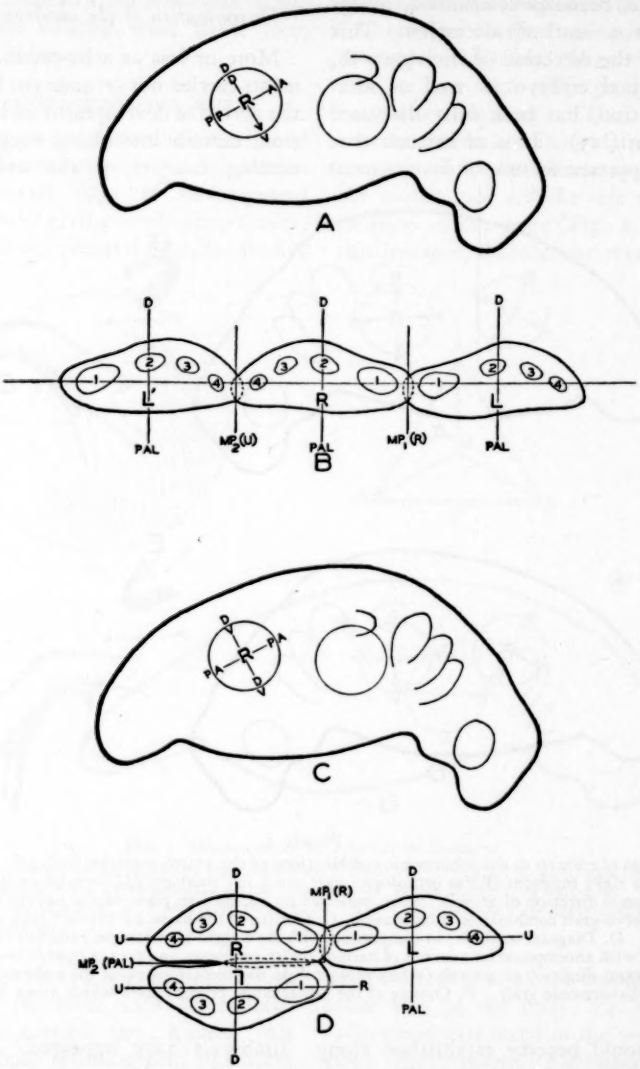

FIGURE 5

A. Diagram of embryo with a harmonic, heterotopic limb graft. B. Showing mirror relationships between the primary (R) limb from such a graft and a possible radial (L) and (or) ulnar (L′) supernumerary. D = dorsal; PAL = palmar; $MP_1(R)$ = first (radial) mirror plane; $MP_2(U)$ = second (ulnar) mirror plane; 1, 2, 3, 4 = digits from radial to ulnar side of limb. (Modified from Harrison, '21, Fig. 4, p. 14.) C. Diagram of embryo with disharmonic limb graft. D. Showing mirror relationship between the disharmonic (L) limb from such a graft and its radial supernumerary (R); also the mirror relationships between the latter and a possible palmar supernumerary (T). $MP_2(PAL)$ = second (palmar) mirror plane. (Other abbr. and acknowledgment as in B. above.)

of reduplication has been the subject of a considerable number of studies. A few observations which are helpful in the present discussion, have come out of these studies. Reversal of asymmetry in the extra limb, a reversal causing it to stand as the mirror image of the primary member, must be due to the establishment of polarity in its anteroposterior axis opposite to that of the corresponding axis of the original limb. This follows from the indifferent condition of the dorsoventral axis and is further demonstrated by observations upon the development of certain limbs which underwent both reduplication and rotation (Swett, '24, '26). We have no crucial experiment upon the exact time at which polarization takes place in the anteroposterior axis of the supernumerary member. However, there is some more or less circumstantial evidence, derived from experiments in which young double buds were transplanted (Swett, '28a), that it occurs very early. Apparently, in the secondary as well as in the primary member, the anteroposterior axis undergoes determination at the time the rudiment is segregated, in the primary with reference to the corresponding axis of the body of the embryo and in the supernumerary with a reversed relationship to the corresponding axis of the primary. Figure 5 presents (A) a harmonic orientation of a transplanted rudiment and (B) the symmetry relations which result when such a graft produces an anterior (L) and (or) a posterior (L') supernumerary. In the case of transplanted limbs, the primary member may or may not be harmonic in the definitive condition but the secondary member apparently has its anteroposterior axis polarized oppositely in either case.

Naturally the above can be applied only to a supernumerary limb which has arisen from the radial or the ulnar border of the primary. In the relatively rare dorsal or palmar reduplications (Fig. 5, D), the definitive conditions of symmetry are due to determination of the dorsoventral axes —the anteroposterior axes being parallel.

THE DORSOVENTRAL AXIS

Owing to studies carried out particularly by Harrison and by Nicholas we have certain definite information on the dorsoventral limb-axis prior to its determination, i.e. during the period of differentiation characterized by only one polarized limb-axis. In the case of *Amblystoma* at least, all the early experiments showed very clearly that the asymmetry of a limb derived from a transplanted rudiment was, in large measure, independent of the orientation imposed upon the dorsoventral axis of the embryonic rudiment. However, in the course of his experments on recovery of posture by rotation, Nicholas found that rotation, under the influence of an operatively rotated ring of surrounding tissue, could be made to take place toward a posture abnormal with respect to the body as a whole. Further, by using larger grafts, with a diameter equal to the width of five somites, it was possible to produce inverted limbs by the same operative orientation which resulted in normally postured members when smaller grafts were used. This finding is contained in an unpublished study, the manuscript of which Dr. Nicholas was kind enough to send to me. The rôle of tissue immediately surrounding the rudiment thus was shown to be most important while factors operating in the body of the animal as a whole had a more indirect effect.

Determination of the dorsoventral axis

Determination of the dorsoventral limb-axis, in the embryonic limb rudiment of urodeles, has been shown to occur at a later period of development than the deter-

mination of the anteroposterior. This is somewhat different from the condition in anurans (Graper, '22, '23, '24, '25, '27) and in the regenerating limb blastemas of urodeles (Milojevič, '23, '24; Lodyženskaja, '28, '29) in which these first two axes appear to undergo simultaneous determination. Figure 6 indicates stages of *A. punctatum*, (A) just before polarization of the second limb axis, (B, C) during the

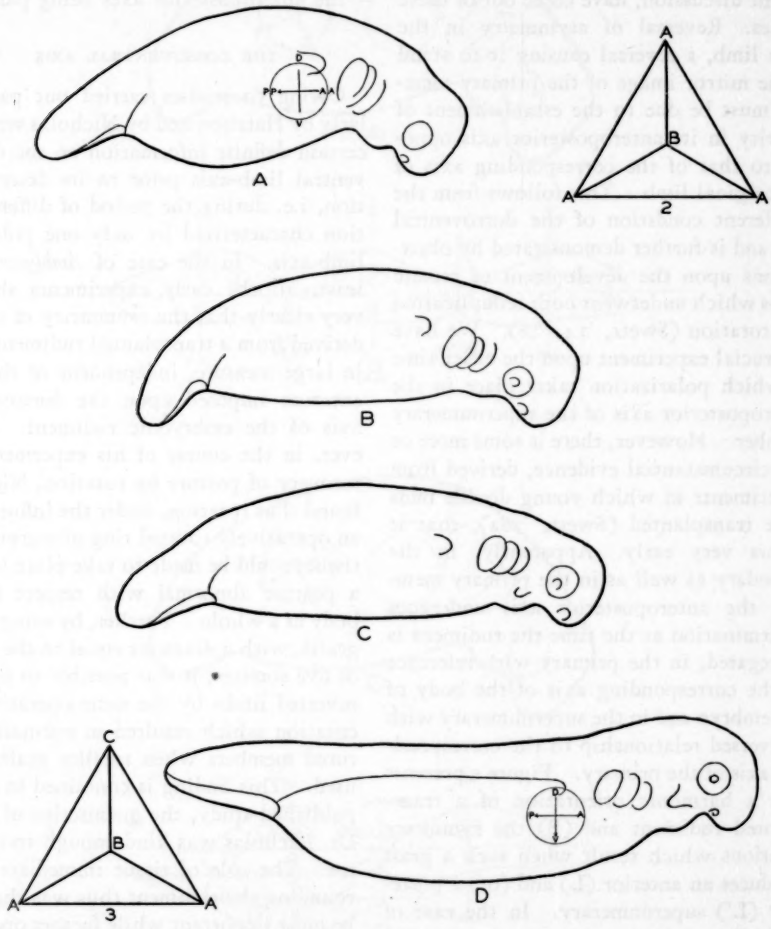

FIG. 6. A SERIES OF DIAGRAMS TO SHOW THE RELATIVE DEGREE OF DEVELOPMENT OF EMBRYOS (A) BEFORE, (B, C) DURING AND (D) AFTER THE DIFFERENTIATION CHANGES LEADING TO DETERMINATION OF THE DORSOVENTRAL LIMB AXIS

A. Embryo stage 32, one limb-axis determined, (2) the corresponding stereodiagram from Fig. 2. B. Embryo stage 33, transitional period. C. Embryo stage 34, transitional period. D. Embryo stage 35, two limb-axes determined, (3) the corresponding stereodiagram from Fig. 2.

transitional period and (D) after determination has been accomplished.

The period at which this axis becomes determined has been investigated in *Triton* by Brandt ('24), in *Amblystoma tigrinum* by Ruud ('26) and Hollinshead ('36), in the axolotl (*A. mexicanum*) by Ruud ('31) and in *A. punctatum* by Swett ('27). Some species variation seemed to have been apparent but a recent study by Hollinshead has indicated that the difference may not be so great as was at first thought. He repeated certain of Ruud's experiments on *A. tigrinum* and paralleled the series with another using smaller grafts. The results showed that the axis in question does not become determined so early in *tigrinum* as in *punctatum*. His findings were somewhat at variance with Ruud's conclusions but the discrepancies appeared to be due chiefly to differences in graft size.

Apparently the periods of dorsoventral-axis determination in the two species are really quite close together, especially when they are compared on the basis of the relative degree of limb development rather than with regard to the stage of development exhibited by the embryo as a whole.

Perhaps the most characteristic finding in limbs grafted after determination of the dorsoventral axis is the inverted posture of the primary limb which results from operative inversion of the rudiment. That it actually develops upside down, instead of being drawn into that position secondarily, has been shown by careful study of the developmental stages in a considerable number of experimental cases. Such a limb does not undergo the reversal of prospective asymmetry shown by limbs developed from younger inverted grafts. Furthermore, the initial direction of growth after inversion is shifted only about sixty degrees from the normal and the asymmetry of the limb is dependent upon the orientation, not of one, but of both determined axes with respect to the body wall. No detailed studies have been made upon rotational recovery of posture in these older stages. The small amount of information at hand has indicated that they behave much like the younger stages in *Amblystoma*, although conditions in *Triton* appear (Brandt, '24) to be different.

Determination apparently not reversible

During the past several years a series of investigations has been under way to test some of the conditions affecting axial determination. The dorsoventral axis was chosen in preference to the others because of the ease with which it can be disoriented, both before and after it has become determined. Certain experiments (Swett, '30), in which inverted rudiments with determined dorsoventral axes were transplanted to brachial and to flank locations on younger embryos, have indicated determination of this axis to be absolute. Although implantation was accomplished some time before the limb rudiments of the recipient underwent determination of the corresponding axis, there was no observable effect upon the graft. It developed into an inverted limb just as it would have done had there been no age discrepancy.

Can determination be delayed?

Preliminary experiments designed to find out whether the process of determination could be accelerated or delayed have not been conclusive, but they do offer a few points of interest. Attempts to delay the process have been completely negative (Swett, '37). Limb rudiments from embryos (Fig. 7, A) just about to enter upon the transitional period in which the dorsoventral limb-axis becomes polarized, were transplanted to younger embryos (Fig. 7, B) without change of orientation. After the donor had reached a stage (Fig. 7, A′) beyond the transitional period and the recipient had grown to a stage (Fig. 7, B′) just before the transitional period, these grafts were removed and implanted upside down on the opposite flank of another

embryo in the same stage of development (Fig. 7, C′). Heterotopic positions were used to avoid complicating factors possibly resident in the normal brachial region. The definitive limbs which developed showed very clearly that there had been no change in the rudiment which fluences brought to bear upon it by the donor. When different orientations were employed at the first or the second operation, the results showed that the relationship of the anteroposterior, or of the dorsoventral, axis to the body wall made no difference.

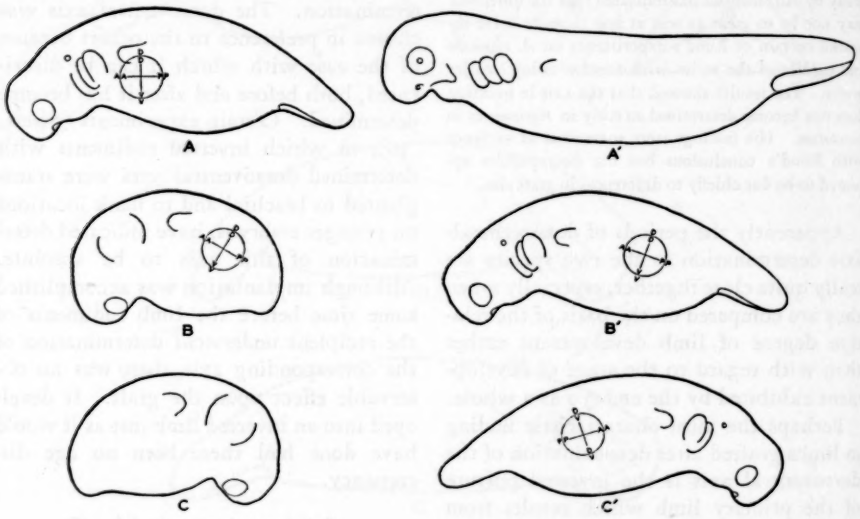

FIG. 7. DIAGRAMS OF EMBRYOS USED IN EXPERIMENTS ON DELAYED DETERMINATION OF THE DORSOVENTRAL LIMB-AXIS

A, B, C. The three embryos chosen in advance of the first operation. A. The donor, stage 32, of the left limb rudiment used for transplantation. B. The recipient, stage 25, of the graft (heterotopic, homopleural, dorsodorsal). C. Extra embryo of same age as B.

A′, B′, C′. The same three embryos at the time of the second operation. A′. Original donor A, now in stage 35. B′. Original recipient B, now in stage 32. C′. Final recipient C, now in stage. (Graft heterotopic, heteropleural, dorsoventral.)

could be ascribed in any way to possible factors in the younger body. In spite of its changed environment the limb rudiment proceeded to undergo dorsoventral-axis determination at approximately the normal rate, as indicated by its development into an inverted limb. The nature of the experiment permitted no conclusions as to whether this step in differentiation was accomplished under the influence of factors in the younger body or as a carry-over from possible pre-transplantation in-

Can determination be accelerated?

Judging from several preliminary series in which attempts were made to expedite the process of determination, transplantation of younger limb rudiments to older embryos may result in some alterations in the process of development. At present, however, there is some doubt whether the effect is a direct one upon the cells of the graft. In these experiments a young rudiment (Fig. 8, A) was transplanted, without change of orientation, to the

body wall of an embryo (Fig. 8, B) just about to enter upon the transitional period of dorsoventral axis determination, and left there for the duration of this period. When the donor had reached a stage (Fig. 8, A′) just before the beginning of the transitional period, the graft was removed from the original recipient (Fig. 8, B′) to the opposite side of the body of another embryo in the same stage of development (Fig. 8, C′). As in the previous series these grafts were inverted at the second operation. Both brachial and flank locations were employed for reception of the first graft (Fig. 8, B) and the second graft was varied as to size (Fig. 8, B′). As might have been expected from the results of Nicholas and of Milojević, inverted limbs were invariably produced when a ring of surrounding tissue was carried over with the graft at the time of the second operation. However, when no extraneous tissue was included the results were quite inconstant. Although all the possible complicating factors have not been ruled out, nor have the results reached a state from which generalizations can be made, it appears that the cells of the rudiment originally grafted were essentially unaffected. If this proves to be true, as the result of subsequent experimentation, we must conclude that the factors resident in the tissue surrounding a younger grafted rudiment have little or no power to fix the polarity of its dorsoventral axis prematurely; although they are, during the

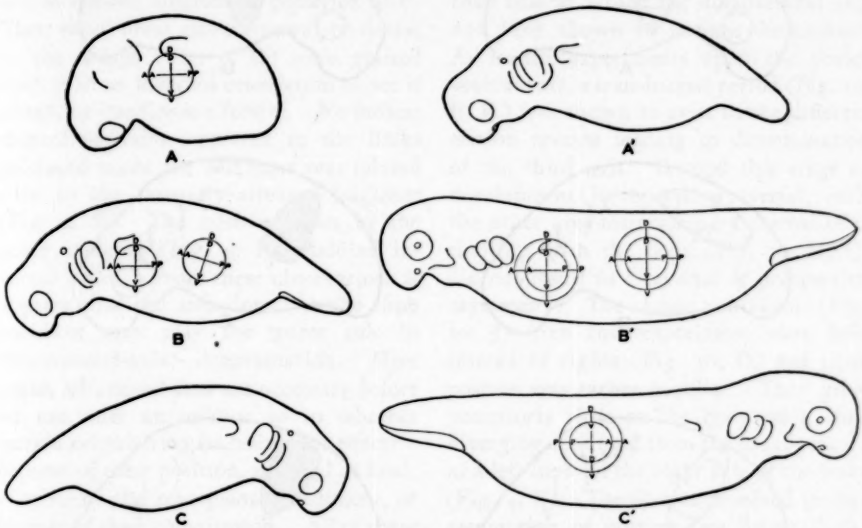

FIG. 8. DIAGRAMS OF EMBRYOS USED IN EXPERIMENTS ON THE ACCELERATION OF DETERMINATION OF THE DORSOVENTRAL LIMB-AXIS

A, B, C. The three embryos chosen in advance of the first operation. A. The donor, stage 25, of the left limb rudiment used for transplantation in normal orientation to left brachial region or flank. B. The recipient, stage 32, of the graft (homopleural, dorsodorsal, orthotopic or heterotopic). C. Extra embryo of same stage as B.

A′, B′, C′. The same three embryos at the time of the second operation. The larger circle around the limb rudiment represents the margin of the "surrounding tissue" included with the rudiment in some of these second grafts. A′. Original donor A, now in stage 32. B′. Original recipient B, now in stage 35. C′. Final recipient C, now in stage 35 (graft heterotopic, heteropleural, dorsoventral).

same period, effective in the process by which the embryo's own limb undergoes determination of this axis. It follows that the timing factor in the determination process is at least partially resident in the rudiment itself. Whether this can be tested experimentally remains to be seen.

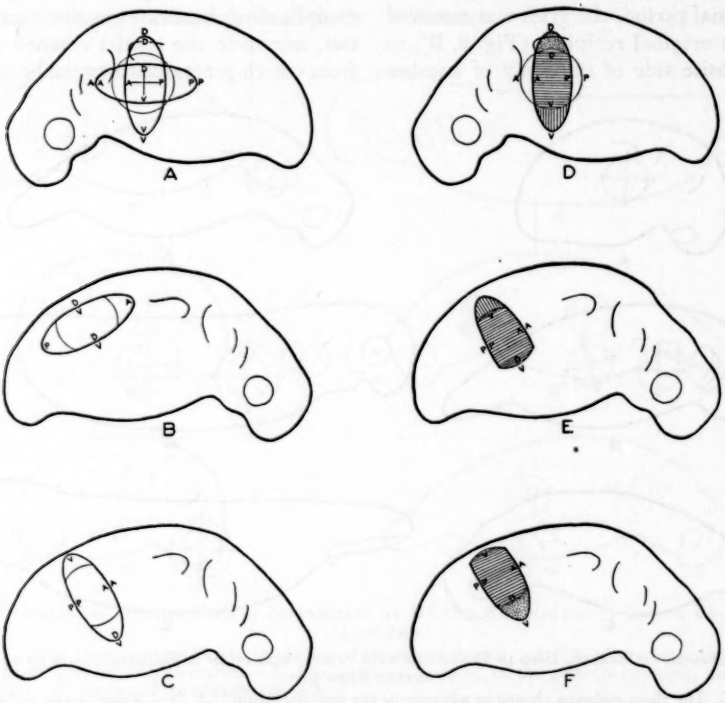

FIG. 9. DIAGRAMS TO SHOW ORIGIN AND PLACEMENT OF GRAFTS COMPOSED OF A PORTION OF THE LIMB RUDIMENT TOGETHER WITH VARIOUS FRAGMENTS OF THE TISSUE SURROUNDING IT

(The orientation of each graft is heteropleural dorsoventral.)

A. Showing the outlines of horizontal and vertical grafts (heavy lines) with respect to the left rudiment of the donor embryo. The margin of presumptive limb-forming material is indicated by light lines within the graft. B. Showing location of the horizontal graft from A on the right flank of another embryo. C. Showing location of vertical graft from A on the right flank of another embryo. D. Donor embryo for grafts including a portion of the limb rudiment (horizontal stripes) together with tissue dorsal (stippled) or ventral (vertical stripes) to it. E. Recipient embryo showing location of graft, from D, composed of limb-forming cells together with the small ventral fragment of surrounding tissue. F. Recipient embryo showing location of graft, from D, composed of limb-forming cells together with the small dorsal fragment of surrounding tissue.

Rôle of adjacent tissue in the process

It seems appropriate to mention at this time another angle from which this problem is being investigated. Inasmuch as Nicholas' experiments had shown the dorsoventral limb-axis to be determined with reference to, or by, the tissue immediately surrounding its base, it became of interest to discover what portion of this ring produced the effect. Consequently, experiments were made with grafts composed (Fig. 9, A) of the limb rudiment together with tissue anterior and posterior, or dorsal and ventral, to it. The

results consisted of reversed limbs when the inverted anterior and posterior extrabrachial areas accompanied the limb graft (Fig. 9, B), and inverted limbs when the dorsal and ventral areas were used (Fig. 9, C). It thus appeared that the factors effective in dorsoventral limb-axis determination might be resident in regions dorsal or ventral to the limb rudiment but not in regions anterior or posterior to it. Then small areas either ventral or dorsal to the anlage (Fig. 9, D) were grafted with it in an inverted orientation to see if either, by itself, was effective. No indication of inversion appeared in the limbs produced when the rudiment was related only to the ventrally situated fragment (Fig. 9, E). The positive cases in the other category (Fig. 9, F) produced inverted limbs. From these observations it appears that the area dorsal to the limb rudiment may play the major rôle in dorsoventral-axis determination. Here again, additional data are necessary before we can offer an opinion as to whether certain neighboring fragments are effective because of their position, original or final, relative to the transplanted rudiment, or because of their constitution. All of these unfinished experiments are presented with considerable hesitancy and with the hope that, if they have any value, they may suggest ways and means for a further attack upon the problem.

THE MEDIOLATERAL AXIS

The next stage of limb-axis differentiation is characterized by polarization of the third and last axis—the mediolateral. Only after this has been accomplished is the asymmetry of the limb really established on a permanent basis. Harrison ('25) showed very clearly that operative reversal of this axis during the so-called tail bud stages of *Amblystoma*, made no difference in the asymmetry or posture of the limb produced. The axis became determined with reference to its surroundings and the limb developed as though no disorientation had been imposed. In the course of experiments upon later stages (Fig. 10, A, E-G), results (Fig. 10, D) duplicating those of Harrison were secured (Swett, '27, '28b) until the embryos reached a stage somewhat more advanced than that at which the dorsoventral axis had been shown to become determined. As in the experiments upon the dorsoventral axis, a transitional period (Fig. 10, E, F.) was shown to exist in the differentiation process leading to determination of the third axis. Beyond this stage of development its operative reversal, with the other axes maintaining a normal relationship with the body (Fig. 10, H, I), did not result in a reversal of prospective asymmetry. The limbs obtained (Fig. 10, J) from this experiment were lefts instead of rights (Fig. 10, D) and their posture was rather peculiar. They grew posteriorly close to the body wall, thus diverging about 90° from the usual posture of a left limb on the right side of the body (Fig. 4, F). The factors involved in this assumption of posture (see Swett, '28b) have not been made clear but the apparent failure of growth from the proximal surfaces in these grafts, coupled with the persistence of the original prospective asymmetry, has taken the developmental question out of the category of the "Bruchdreifachbildung." The explanation may be that these limbs, with their asymmetry already determined, continued to grow in the same general direction as before they were grafted—only shifting enough to avoid growing into the body of the embryo. At all events, their behavior has indicated that after a certain stage (Fig. 10, G) had been reached, the final axis had become irreversibly polarized (Fig. 10, *4*, *5*).

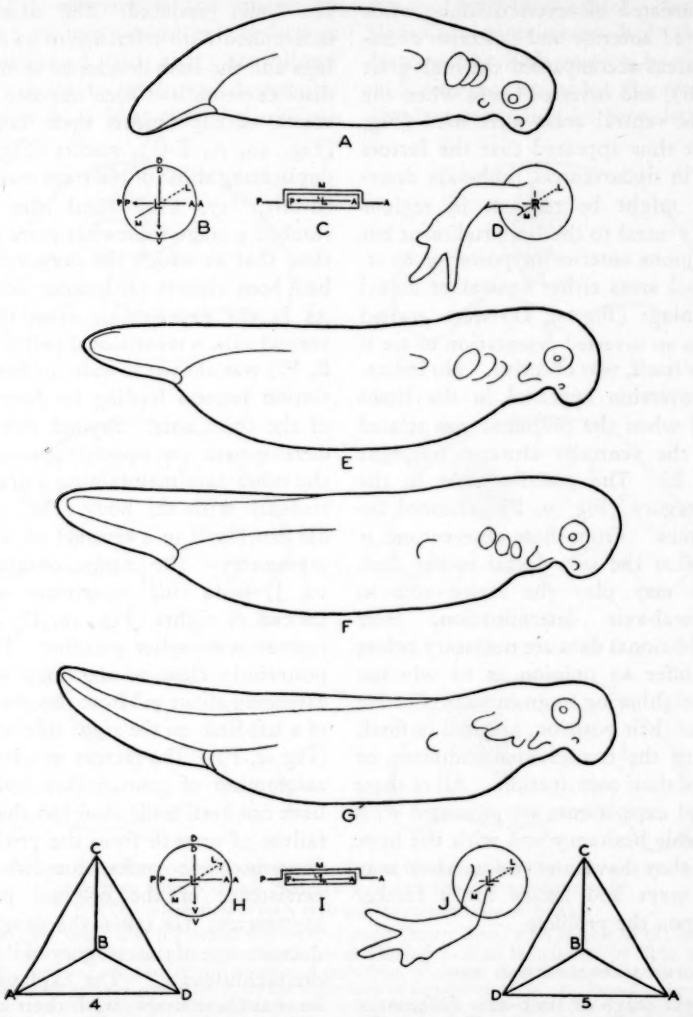

FIG. 10. A SERIES OF DIAGRAMS TO SHOW THE RELATIVE DEGREE OF DEVELOPMENT OF EMBRYOS (A) BEFORE, (E, F) DURING AND (G) AFTER THE DIFFERENTIATION CHANGES LEADING TO DETERMINATION OF THE MEDIOLATERAL LIMB-AXIS

A. Embryo stage 34, mediolateral axis not determined. B. Diagram showing, in lateral view, orientation of grafted limb rudiment with the change of operative orientation affecting only the mediolateral limb-axis (M — L). C. The same condition as in B diagrammed as though viewed from above. D. Outline of the harmonic limb produced by such a graft (B, C) carried out before determination of the mediolateral axis has taken place. E. Embryo stage 35, transitional period. F. Embryo stage 36, transitional period. G. Embryo stage 37, mediolateral axis determined. H, I. Diagrams corresponding to B, C above, same operative orientation but with determination of all the axes indicated by the arrow tips on the three lines corresponding to them. J. Outline of the disharmonic limb produced (contrast with D) when the above graft is made after the third axis has been determined. *4*, *5* Right and left stereodiagrams from Fig. 2 illustrating the axial condition attained by the elements composing the limb rudiment at this stage.

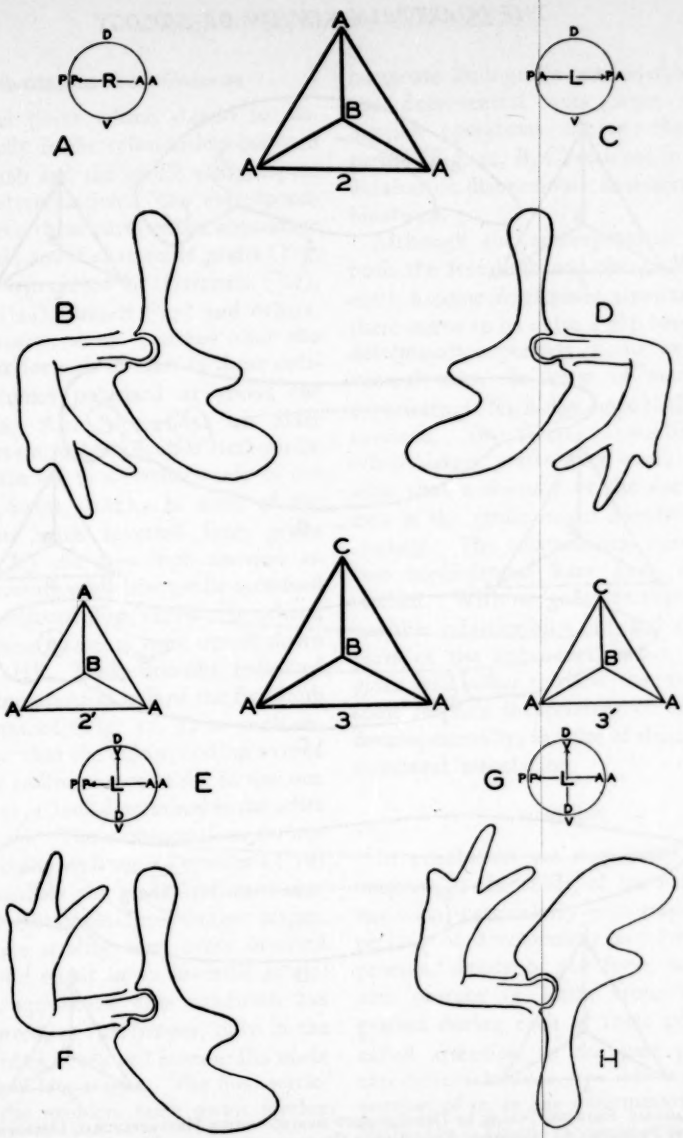

FIG. 11. DIAGRAMS SHOWING HARMONIC AND DISHARMONIC LIMB-GIRDLE RELATIONSHIPS WITH RELATION TO DETERMINATION OF THE ANTEROPOSTERIOR AND THE DORSOVENTRAL AXES OF THE TWO RUDIMENTS

A–D The free limb and shoulder girdle rudiments have only one axis, the anteroposterior, determined (2 from Fig. 2). A. Diagram indicating harmonic orientation of a limb graft. B. A harmonic limb and a harmonic girdle. C. Diagram indicating disharmonic orientation of a limb graft. D. A disharmonic limb and disharmonic girdle. E. Indicating heteropleural dorsoventral orientation of grafted limb rudiment after determination of dorsoventral axis of the free limb (3 from Fig. 2) and before determination of corresponding axis of the shoulder girdle (2′). F. Disharmonic limb-girdle combination composed of a right girdle and an inverted left limb. G. Same orientation and conditions as in E. except dorsoventral axis of girdle (3′) has undergone determination. H. Harmonic limb-girdle combination composed of inverted left elements.

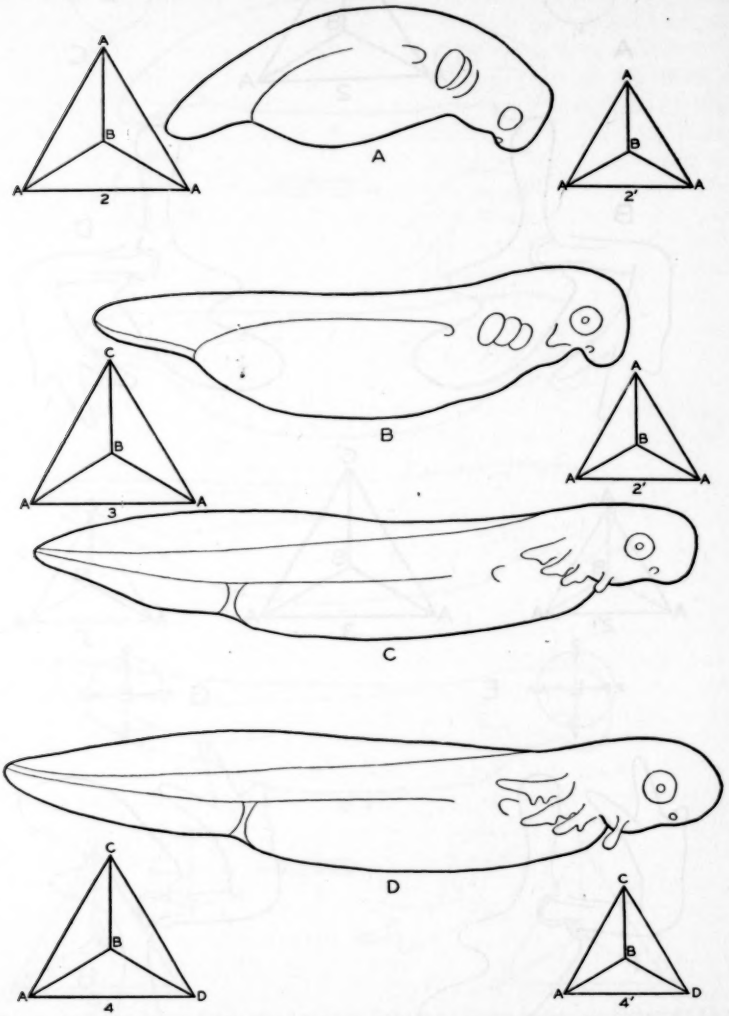

FIG. 12. DIAGRAMS SHOWING STAGES OF DEVELOPMENT DURING WHICH HETEROPLEURAL DORSOVENTRAL LIMB GRAFTS PRODUCE (A) HARMONIC LIMB-GIRDLE COMBINATIONS OF THE TYPE SHOWN IN FIG. 11, B, D; (B, C) DISHARMONIC COMBINATIONS (FIG. 11, F); AND (D) HARMONIC COMBINATIONS LIKE THAT SHOWN IN FIG. 11, H

The corresponding stereodiagrams (*2, 3, 4*) at the left apply to the axial condition in the free limb; those at the right (*2′, 2′, 4′*) to the axial condition in the girdle.

A. Embryo, stage 32, no dorsoventral axis determination in limb or girdle. B. Embryo, stage 35. At this stage, also in stages 36, 37 and 38, the dorsoventral limb-axis (*3* from Fig. 2) is determined, but the corresponding shoulder-girdle axis (*2′*) is not. C. Embryo, stage 38. D. Embryo, stage 39, dorsoventral axis of shoulder girdle has undergone determination.

LIMB-GIRDLE RELATIONSHIPS

A further point which should be discussed briefly is the relationship between the free limb and the girdle with respect to axis determination. The correspondence between these parts of the appendage in harmonic and disharmonic grafts (Fig. 11, A-D) was noted by Harrison ('21), Nicholas ('24), Brandt ('27) and others. The conclusion seems justified that the anteroposterior axis of each of these rudiments becomes polarized at about the same time. After operations on older stages, certain rather peculiar limb-girdle relationships led to a further study of the question (Swett, '28c). In some of the experiments with inverted limb grafts (Fig. 11, E) the free limb showed an inverted posture while the girdle remained normally oriented (Fig. 11, F). In others, both of these elements were upside down (Fig. 11, H). These findings indicated that the dorsoventral axis of the free limb was determined (Fig. 11, *3*) in each instance but that the corresponding axis of the girdle rudiment was labile in the one case (Fig. 11, *2'*) and determined in the other (Fig. 11, *3'*). These observations do not fit in especially well with Detwiler's ('18) conclusions that the girdle rudiment constitutes a mosaic in the younger stages. If this were strictly true, every inverted graft should result in an inverted girdle. However, apparently this condition has been reported, in *Amblystoma*, only in the case of girdles developed from grafts made at relatively late stages. The final settlement of the problem must await further study.

A tabulation of cases on the basis of the stage used for operation resulted in the recognition of three developmental periods. Operations during the first (ending at about the stage shown in Fig. 12, A) and third (beginning with the stage shown in Fig. 12, D) of these periods produced harmonic limb-girdle combinations when the dorsoventral axes were inverted. Similar operations during the second period (Fig. 12, B, C) resulted in the production of disharmonic limb-girdle combinations.

Although the anteroposterior axes of both the free limb and the girdle apparently become determined simultaneously, there seems to be quite a gap between the determination periods of the two dorsoventral axes. In view of more recent experiments (Nicholas, unpublished; Hollinshead, '36; Swett, unpublished) in which larger grafts were used, it is possible that a re-study of the dorsoventral axis of the girdle might narrow this gap slightly. The relationships between the two mediolateral axes have not been studied. Without going further into the possible relationships between these two parts of the appendage, what has been given will suffice to show that they are in some respects independent of each other developmentally, in spite of their intimate structural association.

SUMMARY

In conclusion we may point to some progress in the study of limb-axis determination, particularly with respect to the periods of development involved in the process. Study of the form, asymmetry and posture of limbs from rudiments grafted during each of these periods has called attention to the part played by extrabrachial tissue, possibly a particular portion of it, in the determination of the limb-axis. There is some evidence, at present insufficiently controlled, for assuming that the speed of axis differentiation is not altered materially when the limb rudiment is grafted to an older or to a younger embryo. If established by future experiments, this may necessitate a revision of our present ideas concerning the impor-

tance of the rôle played by the surrounding tissue. The complexity of possible interactions between graft and surroundings renders doubtful a prompt solution of the problem and necessitates the greatest care in establishing adequate control experiments. No one questions the necessity of a better understanding of tissue interactions in development, nor is anyone sanguine enough to believe that the problem can be settled by one method of investigation. The fundamental changes involved do not lend themselves readily to direct observation and must be studied from as many angles as possible. The limitation of this discussion to one such angle should not be construed as a reflection upon the importance of the others.

For the careful execution of the figures accompanying this paper, the writer is indebted to Mr. Elon H. Clark of the Department of Illustration.

LIST OF LITERATURE

Brandt, W. 1924. Extremitätentransplantationen an *Triton taeniatus*. Ein experimenteller Beitrag zum Determinationsproblem. I. Mitteilung. *Arch. f. mikr. Anat. u. Entwcklngsmechn. d. Organ.*, Bd. 103, S. 517–554.

——. 1927. Schultergürteluntersuchungen an transplantierten Gliedmassen bei *Triton taeniatus*. *Arch. f. Entwcklngsmechn. d. Organ.*, Bd. 112, S. 149–183.

Detwiler, S. R. 1918. Experiments on the development of the shoulder girdle and the anterior limb of *Amblystoma punctatum*. *J. Exp. Zool.*, vol. 25, pp. 499–538.

——. 1933. On the time of determination of the antero-posterior axis of the forelimb in *Amblystoma*. *J. Exp. Zool.*, vol. 64, pp. 405–414.

Gräper, L. 1922. Extremitätentransplantationen an Anuren. I. Mitteilung. *Arch. f. Entwcklngsmechn. d. Organ.*, Bd. 51, S. 284–309.

——. 1922. Extremitätentransplantation an Anuren. II. Mitteilung: Reverse Transplantation. *Arch. f. Entwcklngsmechn. d. Organ.*, Bd. 51, S. 587–609.

——. 1923. Determination und Differenzierung. *Arch. f. mikr. Anat. u. Entwcklngsmechn. d. Organ.*, Bd. 98, S. 210–220.

——. 1924. Extremitätentransplantationen an Anuren. IV. Mitteilung. *Arch. f. mikr. Anat. u. Entwcklngsmechn. d. Organ.*, Bd. 102, S. 263–275.

——. 1925. Extremitätentransplantationen an Anuren. V. Mitteilung. *Arch. f. Entwcklngsmechn. d. Organ.*, Bd. 105, S. 1–18.

Graper, L. 1927. Entwicklungsmechanik der Wirbeltierextremitäten. *Ergebn. d. Anat. u. Entwcklngsgesch.*, Bd. 27, S. 693–786.

Harrison, R. G. 1918. Experiments on the development of the fore limb of *Amblystoma*, a self-differentiating, equipotential system. *J. Exp. Zool.*, vol. 25, pp. 413–461.

Harrison, R. G. 1921. On relations of symmetry in transplanted limbs. *J. Exp. Zool.*, vol. 32, pp. 1–136.

——. 1925. The effect of reversing the mediolateral or transverse axis of the fore-limb bud in the salamander embryo (*Amblystoma punctatum* Linn.). *Arch. f. Entwcklngsmechn. d. Organ.*, Bd. 106, S. 469–502.

——. 1933. Some difficulties of the determination problem. *Am. Naturalist*, vol. 67, pp. 306–321.

Hollinshead, W. H. 1936. Determination of the dorsoventral axis of the fore limb in *Amblystoma tigrinum*. *J. Exp. Zool.*, vol. 73, pp. 183–194.

Lodyženskaja, V. 1928. La transplantation des bourgeons de régénération des extrémités de l'axolotl. *Compt. rend. Acad. d. sc. d. l'U.R.S.S.*, Feb. 15, pp. 99–101.

——. 1929. La transplantation des bourgeons de régénération des extrémités de l'axolotl. *Studies, Lab. of Exp. Zool. & Morph., Soviet Russian Academy of Sciences*, pp. 61–120.

Milojevič, B. D. 1923. Über Transplantationen von Beinregeneraten bei *Triton cristatus*. *Verhandl. d. dtsch. zool. Ges.*, Bd. 28 (Juli).

——. 1924. Beiträge zur Frage über die Determination der Regenerate. *Arch. f. mikr. Anat. u. Entwcklngsmechn. d. Organ.*, Bd. 103, S. 80–94.

Nicholas, J. S. 1924. Regulation of posture in the fore limb of *Amblystoma punctatum*. *J. Exp. Zool.*, vol. 40, pp. 113–159.

Ruud, G. 1926. The symmetry relations of transplanted limbs in *Amblystoma tigrinum*. *J. Exp. Zool.*, vol. 46, pp. 121–141.

——. 1931. Die Determination der dv-Achse und die Ursache zur "Resorption" transplantierter Vorderextremitätenanlagen bei Axolotlembryonen. *Arch. f. Entwcklngsmechn. d. Organ.*, Bd. 124, S. 522–570.

SWETT, F. H. 1924. Exceptions to Bateson's rules of minor symmetry. *Anat. Rec.*, vol. 28, pp. 63–77.

——. 1926. On the production of double limbs in amphibians. *J. Exp. Zoöl.*, vol. 44, pp. 419–473.

——. 1927. Differentiation of the amphibian limb. *J. Exp. Zoöl.*, vol. 47, pp. 385–439.

——. 1928a. Relations of symmetry in double limb buds. *J. Exp. Zoöl.*, vol. 52, pp. 149–158.

——. 1928b. Further experiments on the determination of the mediolateral axis of the fore limb of *Amblystoma punctatum* (Linn.). *J. Exp. Zool.*, vol. 50, pp. 51–70.

SWETT, F. H. 1928c. Studies on the shoulder-girdle of *Amblystoma punctatum* (Linn.). I. Determination of its dorsoventral axis. *J. Exp. Zool.*, vol. 51, pp. 389–401.

——. 1930. The permanence of limb-axis polarity. *J. Exp. Zoöl.*, vol. 55, pp. 87–99.

——. 1937. Experiments upon delayed determination of the dorsoventral limb-axis in *Amblystoma punctatum* (Linn.). *J. Exp. Zoöl.*, vol. 75, pp. 143–153.

SEX HORMONES, CARCINOGENICS AND STEROLS

By SEWARD E. OWEN, Ph.D.

Cancer Research Unit, Veterans' Administration, Hines, Illinois

THE gradually accumulating proof of the molecular structure of such substances as cholesterol and other sterols, the genital gland hormones, vitamin D and of organic chemicals having estrogenic or carcinogenic action indicates that these materials have a close chemical and biological relationship.

An exhaustive consideration of one of the major groups mentioned in the title would require volumes for even an imperfect understanding.

The purpose of this presentation is to indicate and discuss some of the more important features of this large and inclusive field.

THE SEX HORMONES

A complete account of the research work done on the male sex hormone would be difficult, but Berthold's (1) transplantation of testes into capons with the production of the now familiar comb and wattles can be cited as an example of the early work and from this we can proceed to the reports of Brown-Sequard (2), to Pezard's (3) work with extracts and to the studies of McGee (4) who obtained an active dealcoholized extract from bull testes. The very microscopic yields obtained from testes extracts precluded accurate chemical investigation of the active lipin-like extracts. The discovery by Loewe *et al.* (5) that the hormone was present in the urine stimulated the chemical attack and Butenandt (6) obtained an active crystalline material from which several derivatives have been made. The molecular structure was shown to be very similar to that of estrin and some sterols. Ruzicka *et al.* (7) have recently prepared active material from cholesterin; this substance gives biological and chemical tests similar to those obtained with the crystals isolated from the testes. Koch *et al.* (8) have reported that the male sex hormone may be specifically adsorbed from urine on a siliceous earth preparation. The formula now accepted for one male sex hormone, known as androsteron, is given in the diagrams. The molecular configuration of an active agent obtained from testes (testerosterone) has not been proven as yet.

While the nomenclature of the female sex hormones is just now being clarified, it may be stated that there are at present two well known hormones obtainable from the ovary, namely the follicle hormone estrin, and the corpus luteum hormone luterosterone. Estriol a third substance is apparently a hydrate of estrin. Luteosterone is obtainable from the corpus luteum, while estrin and estriol may be extracted from the urine of pregnant women.

Allen and Doisy (9) induced the various stages of estrus in castrated animals by injections of an alcoholic extract of ovaries. An impetus to the purification studies resulted from the observation of Ascheim and Zondek (10) that the estrus-producing hormone could be obtained

from the urine of pregnant animals. They also noted the presence of a water soluble estrogenic agent (prolan) in such urines and developed from this observation a diagnostic test for pregnancy. The crystallization of estrin was announced by Doisy *et al.* (11) and by Butenandt (12). The accepted formula evolved from results of work in several laboratories is given in the diagrams.

Chemical studies are being conducted on luteosterone and the formula for this substance has already been postulated. A similar substance called equilenin has been prepared from the urine of mares, Girard (13).

It is apparent from a study of the chemical formulas that these various substances differ but slightly in the character of their polar groups, side chains and the degree of aromatization. All have the phenanthrene nucleus and, as will be shown later, this characteristic is common although not absolutely essential for the various estrogenic substances existing naturally or prepared by artificial means.

Partial hydrogenation of the follicular hormone, estrin, by the addition of two atoms of hydrogen, increases its activity about four fold, the compound resulting is known as dihydrofolliculin. Another peculiar change resulting from this hydrogenation is that the dihydro form is more active orally. If the aromatic ring of this same hormone be completely hydrogenated by the further addition of six more atoms of hydrogen, the resulting substance does not have the property of producing estrus but does assume the properties of the male sex hormone in causing comb growth in capons and it is also capable of causing enlargement of the seminal vesicles in laboratory animals. Trihydroxy-estrin can be converted into ketohydroxy-estrin by vacuum distillation over potassium bisulphate. Several of these chemical relationships and probable derivatives are shown in the diagrams.

The extremely complex molecular make-up, as well as physical and chemical difficulties such as stereoisomerism, will perhaps delay for some time the basic synthesis of these compounds although the sterols from various sources may be used as a chemical starting point in the production of active preparations, namely; estrin can be obtained from the palm nut, estriol from willow catkins, soy beans can serve as a source of the corpus luteum hormone and cholesterin may be utilized as a basis in the preparation of the male sex hormone androsteron.

Synthetic estrogenic compounds have been studied by Cook, Dodds *et al.* (14) and some of these resemble the original estrin in that they contain the phenanthrene nucleus, while others of the anthracene type and not containing the phenanthrene nucleus have been shown to have some definite estrogenic activity when tested on rats, mice and capons. It appears that there are but certain parts of the estrin molecule essential to this biological activity. The important components of artificial estrogenic substances seem to be a condensed carbon ring system with polar groups containing or comprised of oxygen. The phenanthrene nucleus is always present in the more active compounds.

Some synthetic estrogenic compounds are derivatives of rather potent carcinogenic agents, while conversely some carcinogenic agents themselves possess estrogenic activity. Of the latter group we have 1:2 benzpyrene and 5:6 cyclo penteno 1:2 benzanthracene. The chief pharmacological action of these compounds is that of carcinogenesis, the estrogenic action being feeble although definite and produced with rather high dosages as compared to the dosage required for

carcinogenesis. The dibenzanthracene compound is estrogenic when in a diol form and suitably hydrogenated, while in the aromatic state it is carcinogenic. This is illustrated on Chart 3.

Ergosterol, neo-ergosterol and calciferol also cause estrus when given to laboratory animals in considerable dosages, namely about one hundred milligrams. This dosage is many times the amount essental to protect the experimental rat against rickets. This pharmacological action

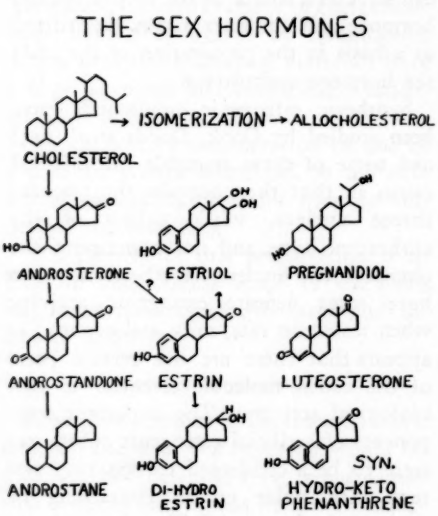

CHART 1

may be a factor in the new therapy for arthritis, which employs excessively high dosages of these and allied substances.

While the excessive cellular proliferation occurring in the early stages of estrus bears a superficial resemblance to certain phases of carcinoma, it is more likely that the chemical skeleton key comparison of Dodds (*loc. cit.*) for these related phenomena and causal compounds fits the facts better. At least the specificity of hormone action may now be severely questioned. Of interest here is the fact that certain types of cancer in the male, Owen and Cutler (15) and Fortner and Owen (16), are associated with excessive urinary outputs of water soluble estrogenic substances. It is not uncommon that reactions as given by Ascheim and Zondek (*loc. cit.*) for the diagnosis of pregnancy in the normal female, may be obtained from the urine from males suffering with teratoma or chorionepithelioma testis.

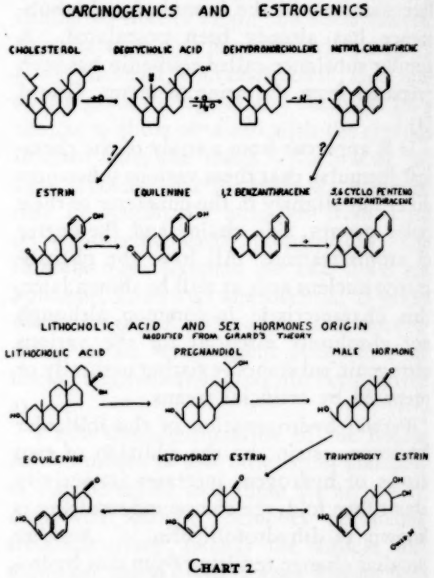

CHART 2

In the course of development and study of these hormones the work has proceded from transplants of glands, injections of extracts, chemical purification and formula determination and the artificial production of agents of known chemical formula.

CARCINOGENIC SUBSTANCES

With these materials a quite similar development period exists, dating from the observation of Yamagiwa and Ichigawa (17) that the experimental applica-

tion of tars produced carcinoid changes in laboratory animals. The fractionation and chemical isolation of the constituents led to the discovery that hydrocarbons of the polycyclic aromatic type were likely to be carcinogenic. Kennaway (18) by the heating of isoprene and acetylene in hydrogen obtained a mixture of compounds some of which were carcinogenic. Synthesis of a series of these compounds by Cook *et al.* (19) resulted in the development of substances related to benzanthracene, which possesed more or less carcinogenic activity. The most important of these are 1:2:5:6 dibenzanthracene, 1:2 benzpyrene and 5:6 cyclo penteno 1:2 benzanthracene. As is shown in the diagrams of formulas, it will be noted that these compounds possess characteristics in common with the estrogenic hormones. Similarity in formula may be carried further if one compares the male sex hormone, ergosterol, cholesterol, several of the alkaloids and other substances such as toad poisons and bile acids.

Since the carcinogenics and estrogenics seem closely related chemically and because it was possible to use some carcinogenics as estrogenics, it was only natural that scientists would attempt to use the estrogenic substances in producing or enhancing the appearance of cancer in animals. Lathrop and Loeb (20) have shown that it is possible to decrease the percentage of naturally occurring cancer, in specific strains of mice that normally show cancer by early castration or ovariectomy. Reduction of the cancer incidence rate in similar mice by the prevention of breeding is also possible. These studies suggest the possibility that the sex hormone in the female animal, at least, coöperate with hereditary factors in causing early breast cancer. The follicular hormone is known to cause mammary proliferation in experimental animals, Loeb and Hasselberger (21) and this hormone has been used in attempts to induce cancer of the breast in animals. Lacassagne (22) used folliculin benzoate, which is slowly absorbed, and reported that mammary cancer occurred in male mice which were injected with this substance. Burrows (23) using keto-hydroxy estrin in benzene has noted one instance of mammary cancer in a male

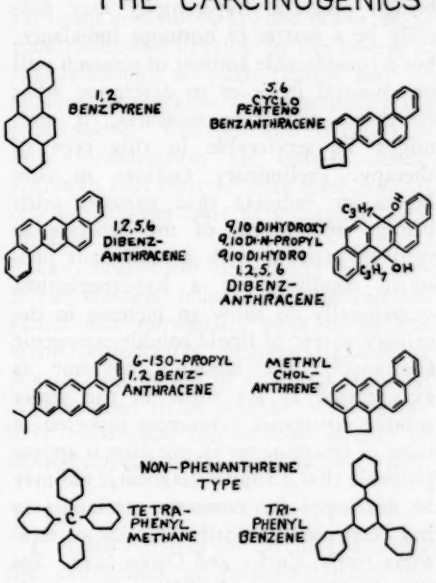

CHART 3

mouse apparently caused by repeated painting of the animal with the solution. He has also shown that prolonged administration of estrin to mice causes hyperplasia and metaplasia in the prostate gland. The latter observation has raised the question whether the benign enlargement of the prostate in elderly men may be due to the action of an estrogenic hormone, and whether this action might be reversed by appropriate balancing of

the hormones in the body by means of injections. It is well to remember that there is considerable similarity in the structure of the male and female sex hormones, and that in the female the germinal tissue produces estrin which inhibits the anterior pituitary gonadal stimulation. Androtin fails to give complete results when used in replacement therapy for castrates and here it has been noted also that a prostatic hypertrophy results following such therapy. It is apparent that benign prostatic hypertrophy may possibly be a matter of hormone imbalance, but a considerable amount of research will be essential in order to determine what corrective endocrine measures, if any, might be serviceable in this type of therapy. Preliminary findings in this laboratory indicate that patients with benign enlargement of the prostate as well as patients with a malignant prostatic condition or a hypernephroma occasionally do show an increase in the urinary output of lipoid soluble estrogenic substances. The amounts are not as exaggerated as are those of the water soluble estrogenic substances reported in cases of teratoma testis, nor does it appear probable that a simple diagnostic aid may be developed for prostatic carcinoma as has been used clinically in cases of teratoma testis, Cutler and Owen (24). Patients with benign or malignant prostatic conditions do not show an excessive urinary output of the prolans.

From a perusal of the diagrams we may postulate some reason for the occurrence of the female sex hormone in the male and vice versa. The production of estrin in male mammals and the existence of the male hormone in female tissues or fluids might be explained by assuming that estrin in the male is a transformation product of the male hormone which is produced in large quantities in the testes. Chemically a dehydrogenation of androsteron to estrin may take place, the estrin then being excreted. In females, the male hormone might be an initial state in the formation of estrogenic substances and some unconverted male hormone might be excreted. It is true that small amounts of the opposite sex hormone may be found in the urines of humans.

THE STEROLS

The complex chemical formulae of the sterols has necessitated a slower development of knowledge regarding them. The relationship of sterols to hormones was first shown by Butenandt (25) who was able to produce 1:2 dimethyl phenanthrene from folliculin and from a stearin derivative. This observation at once connected these important hormones with matter common in all tissues, the sterols. Methyl cholanthrene, a highly active carcinogenic chemical can be obtained from sterols as is shown in the diagrams, thus the carcinogenics and the estrogenics may be obtained from a common chemical substance which

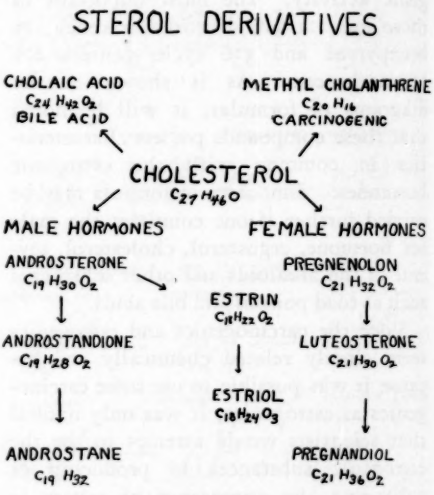

CHART 4

exists in body tissues. The reactions essential in forming the carcinogenic substances from cholesterol, for instance, constitute such chemical changes as are common in the body for other molecules. These changes are mainly ones of oxidation, reduction, dehydrogenation and dehydration. Whether the body metabolism can effect the conversion of a straight chain into a carbon ring compound as is illustrated for the cholesterol changes, is still questioned although Edisbury *et al.* (26) believe they have proof that a similar cyclization of a highly unsaturated compound does occur.

It seems entirely probable that the various sex hormones are prepared in the body from the sterols. It is also possible that the carcinogenic agents might be formed in the body cells by a degradation metabolism of the sterols. Here it may be of interest to point out that the cholesterol content of tumors is very high and in spite of a fairly high phospholipid content, the ratio of cholesterol to phospholipid is unusually large. Various workers have made extracts of tumors, more especially the lipomas for sex hormone content and have reported finding significant amounts of these endocrines. More controls are still needed.

DISCUSSION

Rather weak although definite carcinogenic effects have been noted for chemicals not possessing the phenanthrene nucleus, Morton *et al.* (27) who have shown that symmetrical triphenyl benzene and tetraphenyl methane will produce cancer in mice. Thus the field of carcinogenics may be more broad than hitherto supposed.

The assistance in the production of cancer, given by the sex hormones seems limited to the sex organs or to the secondary sex organs, and requires periods of application of some time. The carcinogenic material from tar or as prepared synthetically, is not specific as to field of action for cancerous changes are induced in the tissues which have long contact with the agent. These agents are also more certain in action than the hormones. For both types of material,the longer the stimulus is applied the greater is the incidence of cancer and the earlier the cancer will appear. There is a preparatory period for both types of chemicals after which the agent need not be applied as the cancer conditions will develop in the course of time although no such change may be apparent at the time of discontinuing the applications. Irritation and its concomitant inflammation are usually absent although it is believed that some gradual cellular changes must be induced in each instance.

The mechanism underlying the cancerous changes induced by the carcinogenics and estrogenics seem to depend upon proliferative processes extending over a long period of time but the final action apears to be indirect. One of the basic etiological factors may include an altered cellular metabolism for the sterol.

SUMMARY

1. A discussion of the carcinogenics and the estrogenics is presented from the chemical and biological angles.

2. The relationship of the sterols to the sex hormones and to the carcinogenics is illustrated.

3. Artificial sources of the hormones are given and these are compared to the sources of carcinogenic substances.

4. The possible rôle of sterol metabolism and cellular dysfunction in sterol degradation is presented as a probable source of carcinogenics and estrogenics in the body.

5. The common chemical nucleus of the sterols, carcinogenics, sex hormones,

vitamins, bile salts and acids and of some common alkaloids is illustrated, and discussed.

This paper is published with the permission of the medical director of the Veteran's Administration, who assumes no responsibility for the opinions expressed or conclusions drawn by the author.

LIST OF LITERATURE

1. Berthold, A. A. Transplantation der Hoden. *Arch. f. Anat. Physiol. u. wissenschaf. Med.* 1: 42–46, 1849.
2. Brown-Sequard, C. E. Demontrant la puissance dynamogenique chez l' homme d'un liquide extrait de testicle d'animaux. *Arch. de physiol. norm et path.* 21: 651–658, 1889; 21: 739–746, 1889.
3. Pezard, A. Sur la détermination de caractères sexuels secondaires chez les gallinaces. *Compt. rend. acad. de Sci.* 153: 1027–1029, 1911, and: Secondary sexual characteristics and endocrinology. *Endocrinology* 4: 527–540, 1920.
4. McGee, L. C. The effect of the injection of a lipoid fraction of bull testicle in capons. *Proc. Inst. Med. Chicago.* 6: 242–244, 1927, and: Biological Activity of Testicular Extracts. Doctoral Dissertation. Univ. Chicago. 1927.
5. Loewe, S., Voss, H. E., Lange, E. and Wahner, A. Sexualhormonbefunde im männlichen Harn. *Klin. Wchnschr.* 7: 1376–1377, 1928.
6. Butenandt, A. Über die chemische Untersuchung der Sexualhormone. *Zeit. angew. chem.* 44: 905–908, 1931.
7. Ruzicka, L., Goldberg, M. W., Meyer, J., Brungger, H. and Eichenberger, E. Zur Kenntnis der Sexualhormone II: Über die Synthese des Testikelhormons (Androsteron) und Stereoisomerer desselben durch Abbau hydrierter Sterine. *Helvetia chimica Acta* 17: 1395–1406, 1934.
8. Gallagher, T. F., Koch, F., and Dorfman, R. I. Procedure for quantitative extraction of sex hormones from urine. *Proc. Soc. Exp. Biol. and Med.* 33: 440–444, 1935.
9. Allen, E. and Doisy, E. A. An ovarian hormone. Preliminary report on its localization, partial purification and action on test animals. *Jour. Am. Med. Assn.* 81: 819–821, 1923.
10. Aschheim, S. and Zondek, B. Hypophysenvorderlappenhormon und Ovarialhormon in Harn von Schwageren. *Klin. Wchnschr.* 6: 1322–1323, 1927, and: Hypophysenvorderlappen und Ovarium, Beziehungen der endokrinen Drüsen zur Ovarialfunktion. *Arch. f. Gynäk.* 130: 1–45, 1927.
11. Doisy, E. A., Veler, C. D. and Thayer, S. A. Folliculin from urine of pregnant women. *Amer. Jour. Physiol.* 90: 329–330, 1929.
12. Butenandt, A. Untersuchungen über das weibliche Sexualhormon. Darstellung und Eigenschaften des kristallisierten "Progynons." *Deutsch. med. Wchnschr.* 55: 2171–2173, 1929.
13. Girard, A. La chimie des hormones sexuelles. *Bull. soc. chim. biol.* 15: 562–606, 1933.
14. Cook, J. W. and Dodds, E. C. Sex hormones and cancer producing compounds. *Nature* 131: 205–206, 1933. See also: Dodds, E. C. The hormones and their chemical relations. *Lancet* 216: 987–992, 1934.
15. Owen, S. E. The biologic diagnosis of teratoma testis. *Jour. Lab. and Clin. Med.* 20: 296–301, 1934. See also: Owen, S. E. and Cutler, M. Diagnosis of teratoma testis by biologic assay of prolans. In press; *Med. Bull. U. S. Veterans' Adm.*
16. Fortner, H. C. and Owen, S. E. Chorionepithelioma in the male. *Am. Jour. Cancer* 25: 89–97, 1935.
17. Yamagiwa, K. and Ichikawa, K. Ueber die kunstliche Erzegung von Carcinom, IV. *Gann* 11: 19–26, 1917. See also: Experimentelle Studie über die Pathogenese der Epithelialgeschwülste. *Mitt. a. d. Med. fak. d. K. Univ. zu Tokio.* 15: 295–344, 1915–1916.
18. Kennaway, E. L. The formation of a cancer-producing substance from isoprene (2 methyl butadiene). *Jour. Path. and Bact.* 27: 233–238, 1924. See also Experiments on cancer-producing substances. *Brit. Med. Jour.* 2: 1–4, 1925, and: Further experiments on cancer-producing substances, *Biochem. Jour.* 24: 497–504, 1930.
19. Cook, J. W., Hieger, I., Kennaway, E. L. and Mayneord, W. V. The production of cancer by pure hydrocarbons. *Proc. Roy. Soc. Brit.* 111: 455–484, 1932.
20. Lathrop, A. E. C. and Loeb, L. Further investigations on the origin of tumors in mice, III. On the part played by the internal secretions in the spontaneous development of tumors. *Jour. Cancer Res.* 1: 1–19, 1916; see also Loeb, L. Internal secretions as a factor in the origin of tumors. *Jour. Med. Research*, 40: 477–496, 1919.
21. Loeb, L. and Hesselberger, C. The cyclic changes in the mammary gland under normal and pathological conditions. *Jour. Exper. Med.* 25: 295–304, 1917; see also, The changes in the

pregnant guinea pig, the effect of lutein injections and the correlation between the cycle of the uterus and ovaries and mammary gland. *Jour. Exper. Med.* 25: 305–312, 1917.

22. Lacassagne, A. Apparition de cancer de la mamelle chez la souris mâle, soumise a des injections de folliculine. *Compt. rend. acad. d. Sc.* 195: 630–632, 1932.

23. Burrows, H. Pathological conditions induced by oestrogenic compounds in the coagulating gland and prostate of the mouse. *Am. Jour. Cancer.* 23: 490–512, 1935. See also: Carcinoma occurring in a male mouse under continued treatment with oestrin. *Am. Jour. Cancer.* 24: 613–616, 1935.

24. Cutler, M. and Owen, S. E. Clinical value of prolan A determinations in teratoma testis. *Am. Jour. Cancer* 24: 318–325, 1935.

25. Butenandt, A. Uber die stoffliche Charackterisierung der Keimdrüsenhormone; ihre Konstitutionsermittlung und Künstliche Herstellung. *Deut. med. Wchnschr.* 61: 781–786, 1935.

26. Edisbury, J. R., Morton, R. A. and Lovern, J. A. Absorption spectra in relation to constituents of fish oils. *Biochem. Jour.* 27: 1451–1460, 1933.

27. Morton, A. A., Clapp, D. B. and Branch, C. F. New cancer producing hydrocarbons. *Science* 82: 134–135, 1935.

CONTROLLING FACTORS IN DROSOPHILA POPULATION GROWTH

By C. P. WINSOR

Biological Laboratories, Harvard University, Cambridge, Mass.

PEARL'S studies of *Drosophila* populations have established the fact that the logistic equation describes the growth of such populations with reasonable accuracy. He has further demonstrated that increasing density of population has definite effects on fecundity and fertility in *Drosophila*. It seems worth while to consider how far the facts and relations so far determined are adequate to account for the regulation of population numbers.

A few words as to the experimental technique are called for. The experiments are of three kinds. There are, first, experiments on population growth (1), in which a small initial population is placed in a bottle with standard food substrate (banana-agar seeded with yeast) and subsequent census counts taken. Second, there are experiments on mortality (2). In these adult flies are taken at emergence and placed in one-ounce vials. Thereafter deaths are noted as they occur; the flies are periodically transferred to fresh bottles. Third, there are fertility experiments. Of these there are two types, dealing with net fertility (imagoes produced per female-day) and with fecundity (eggs produced per female-day). In the net fertility experiments (3, 4) adult flies are taken at emergence and placed in milk bottles with the standard agar-yeast substrate, left a few days and transferred to new bottles. The progeny flies are counted on emergence. In the fecundity experiments (5), by one or another device it is provided that the flies shall oviposit on a surface which can be removed from the bottle, so that the eggs can be counted.

We may now attempt some analysis of these experimental results, with a view to determining how far the facts which have been established about fertility and mortality are adequate to account for the results obtained in the population growth experiments. The computations are necessarily rough, but should give satisfactory estimates of the orders of magnitude of the quantities involved.

We may consider first the growth of experimental populations of *Drosophila*. It appears that such populations grow along a sigmoid which may be fitted adequately with a logistic. The limiting population, in half-pint bottles on banana-agar, is of the order of 210 flies per bottle (Pearl, 1, p. 35). We do not know the sex-ratio; we shall assume, when necessary, that half of these are females. [From L'Héritier and Teissier's work (6) we might expect that more than half would be female.]

Consider now what can be said of this asymptotic density of 210 flies per bottle. First, what will be the egg production at this density? Using Pearl's (5) equation (1), and extrapolating to a density of 210, we obtain a predicted egg production of about 244 eggs per day. This figure is not more than an indication of order of magnitude, for several reasons. First, it is based on the first 13 days after emergence, and makes no allowance for the age composition of the actual population. Second, synthetic food, changed daily, was used. Third, the food area was about one-quarter of that in the population experiment. Fourth, the extrapolation involved is considerable. It would

not be surprising if the true figure differed from this by a factor of two or three.

We cannot use this figure of egg production directly, because we have no direct information on pre-imaginal mortality. We have, however, figures (Pearl and Parker, 3) which give us net fertility (i.e. adult flies emerging) as a function of population density. [We use these rather than the Pearl, Allen, and Penniman figures of 1926 (4) as being more closely comparable with the population growth experiments.] With these 1922 data, extrapolating to density 210 by Pearl's equation (xxxiii), we find a total of 20 imagoes per day emerging. This figure is probably as reasonable as we can get. It corresponds, in a stationary population of 210, to a mean imaginal duration of life of about 10.5 days.

We should now naturally inquire as to the expectation of life of *Drosophila* in half-pint bottles on banana-agar at a density of 210 flies per bottle. Unfortunately Pearl's life table data are all obtained using one-ounce vials, and one is in considerable doubt as to what sort of correspondence to establish with half-pint bottles. If we asume that flies per unit volume is the significant measure of density, then we should use the figures for density 30–35 flies in the one-ounce vials. If we assume that flies per bottle is controlling, we should use the figures for 210 flies per one-ounce vial. The truth probably lies between these extremes. If, however, we take some such figure as 100 flies per ounce vial, we find the further difficulty that we have no figures for constant density; all the data were obtained for a given initial density, which continuously decreased as flies died off. The best that we can say is that under these conditions, expectation of life lies somewhere between 40 days and 10 days. This is not too far from our previous figure of 10.5 days in the stationary population.

We next observe that there is a wide discrepancy between the figure of 244 eggs per day and 20 emerging adults per day. On their face, these figures indicate a pre-imaginal ("infant") mortality of around 90 per cent. If we scale down the eggs by a factor of three, we still have a mortality of around 70 per cent. Pretty clearly, there must be a large infant mortality, which, in any complete study of population dynamics, would need careful evaluation.

We can perhaps estimate the order of magnitude of this mortality more directly by a comparison of the density-net fertility figures with the density-fecundity figures. We use the figures of progeny per female-day on synthetic food (Pearl, *et al.*, 4) rather than the 1922 figures because the egg production figures are obtained with synthetic food; and the figures of eggs per female-day (Pearl, 5).

DENSITY (FLIES/BOTTLE)	PROGENY/ FEMALE-DAY	EGGS/FEMALE-DAY
2	34.4	19.4
4	25.1	17.4
8	11.1	14.2
16	4.9	13.5
32	1.9	8.2
64	1.0	4.4
128		2.8
256		2.8

It is evident that these figures are not directly comparable, since they purport to show more progeny appearing at low densities than there were eggs laid. However, we have to remember that for technical reasons (for which see Pearl, 5) the area available for oviposition in the egg-production series was only about one quarter that in the progeny series. Now according to Pearl (5) the significant measure of population density for egg-production is flies per unit food area. We may therefore reasonably compare a given density of egg production with a

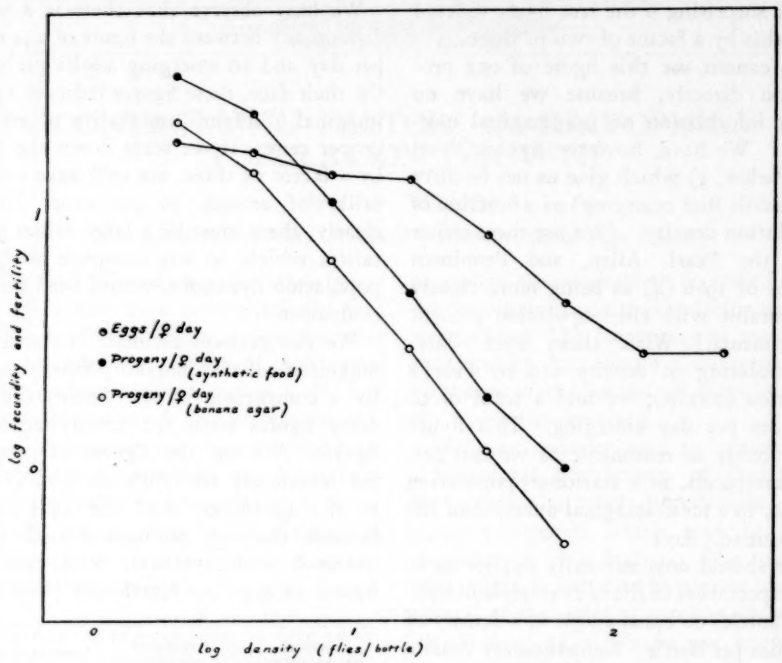

FIGURE 1

nominal density in the progeny series four times greater, and set up our comparison thus:

DENSITY (EGG PRODUCTION)	EGGS FEMALE-DAY	DENSITY (PROGENY SERIES)	PROGENY/ FEMALE-DAY	PRE-IMAGINAL MORTALITY
		2	34.4	
		4	25.1	
2	19.4	8	11.1	43%
4	17.4	16	4.9	72%
8	14.2	32	1.9	87%
16	13.5	64	1.0	93%
32	8.2			
64	4.4			
128	2.8			
256	2.8			

All these calculations are only fit to give orders of magnitude, if we remember the approximations which have been necessary. On the whole, however, they agree rather well together, and the results seem not too improbable. If they are at all near the truth they indicate (1) that there is a high infant mortality in *Drosophila* under conditions of crowding; and (2) that this mortality is markedly affected by density. It would appear that this is very probably an important factor in the control of *Drosophila* populations—very probably of more importance than imaginal death-rates as affected by density, or than fecundity rates as affected by density.

Another way of making the comparison is by plotting the density-fertility and density-fecundity results on double logarithmic paper. In such a plot the significant comparison is between slopes, not between absolute positions relative to

either the vertical or horizontal scales. It is at once clear that the density-net fertility curve is much steeper than the density-fecundity curve, indicating the existence of a component of infant mortality which increases with increasing density of population.

We may perhaps note also the results which L'Héritier and Teissier (6) have briefly reported. By a technique due to Pearl, *et al.* (2) *Drosophila* populations are maintained at saturation levels, with a constant supply of fresh food. In their experiments a saturation population of 3290 imagoes was reached. (Of these about two thirds were females, due to higher mortality among male larvae.) The rate of emergence of adults averaged 141 per day, giving a mean duration of life of 23.3 days. The pre-imaginal mortality was from 98 to 99 per cent. This indicates an egg production per female-day of somewhere from 3.2 to 6.4 eggs. Unfortunately the information as to the conditions of the experiment is insufficient to permit any real comparison with Pearl's results; it would appear, however, that there are no vital discrepancies.

To summarize: the data on fecundity and fertility relative to density of population in *Drosophila* indicate a pre-imaginal mortality varying markedly with density. This mortality may reach 90 to 99 per cent at high densities such as correspond to saturation levels of population. It seems highly probable that this mortality is a factor of major importance in the regulation of numbers.

LIST OF LITERATURE

(1) Pearl, R. 1925. The Biology of Population Growth. *New York*, Knopf.

(2) Pearl, R., Miner, J. R., and Parker, S. L. 1927. Experimental studies in the duration of life. XI. *Am. Nat.*, 61: 289–318.

(3) Pearl, R., and Parker, S. L. 1922. On the influence of density of population upon rate of reproduction in *Drosophila*. *Proc. Nat. Acad. Sc.*, 8: 212–219.

(4) Pearl, R., Allen, A. L., and Penniman, W. B. D. 1926. Culture media for *Drosophila* II. *Am. Nat.*, 60: 357–366.

(5) Pearl, R. 1932. The influence of density of population upon egg production in *Drosophila melanogaster*. *J. Exp. Zool.*, 63: 57–84.

(6) L'Heritier, P., and Teissier, G. 1933. Étude d'une population de Drosophiles en équilibre. *Compt. rend. Acad. Sc. Paris*, 197: 1765.

NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to Dr. Raymond Pearl, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *1901 East Madison Street, Baltimore, Maryland, U. S. A.*

BRIEF NOTICES

EVOLUTION

WHY BE AN APE? *Observations on Evolution. By A London Journalist. Preface by Admiral Sir George F. King-Hall. Illustrations by W. D. Ford. Marshall, Morgan and Scott, London; Zondervan Publishing House, Grand Rapids.* $1.00. $7\frac{1}{4}$ x $4\frac{7}{8}$; 144; 1936.

The author of this work is one of those strange creatures that delight in trying to fan into flame the dying embers of a nearly forgotten conflict of bygone ages. There is no good reason why such a book should ever be written. Vituperative and intolerant language is never becoming to any author, least of all to one actuated by religious motives, for we naturally expect a more sympathetic attitude toward, and a greater toleration for, the religious beliefs of others from a follower of the Man of Galilee than from the crass materialist.

That modern thinkers are not unanimously agreed as to all details of evolution no one will deny. Had the author of this work (who for obvious reasons prefers to remain anonymous) been content to attack a single phase of the subject he might conceivably have made out a plausible case, but instead he undertakes to demolish the entire structure, and so draws heavily on every scientific writer of any note, selecting and isolating odd texts here and there, discarding what he cannot use, in order to forge an instrument wherewith to confute other writers. Onto his *index expurgatorius* go the technical works of Darwin, Weismann, DeVries, and MacBride; and also the more popular but not less scientific works of Fiske, Drummond, and LeConte. If he were consistent the book of Genesis would also have to be consigned thither willy-nilly, for the Elohistic narrative of creation is frankly evolutionary in declaring that man is the culmination of a long series of upward steps from the lowest forms of life.

To such an author it must be disconcerting to find passages in the Psalms, the books of Deutero-Isaiah and Jeremiah, and the Epistle to the Romans, which indicate how receptive to the evolutionary point of view the minds of the writers of these books were, and it must be even more so to remember that among the ecclesiasts of a later day who were philosophical evolutionists must be included Gregory of Nyssa, Augustine of Hippo, Albertus Magnus, Thomas Aquinas, Francis of Assisi, and Giordano Bruno. One wonders if he realizes that responsibility for the adoption by the Christian Church of the doctrine of special creation (a doctrine, incidentally, derived not from Christian or Hebrew sources, but from Plato) rests with Francisco Suarez, *S.J.*, a devoted disciple of the philosophy of Scholasticism with its insistence on the immutability of types, who died only three short centuries ago?

Lest it be thought that too much space

has been given to discussing what the author should have said, and too little to what he really has said, a brief quotation which seems to epitomize the whole thought of the book may appropriately be cited here: "Really, if believing in the ape ancestry of man is humility, and accepting the Bible's declaration of his Divine ancestry is snobbery, I'm for snobbery every time!" Perhaps we have here the explanation of how books like this get written. Perhaps they are the natural product of snobbish intellects that seek to conceal inferiority complexes by rushing in blindly and recklessly where angels are said to tread with humility and reverence.

If this work should win any considerable number of adherents—which is unthinkable—the great loss would be not to science but to religion.

DIE HOLARKTIS. *Ein Beitrag zur diluvialen und alluvialen Geschichte der zirkumpolaren Faunen- und Florengebiete.*

By W. F. Reinig. Gustav Fischer, Jena. RM. 7.50. 10 x 6¾; vii + 124; 1937 (paper).

The author has attempted to explain the relationship of the flora and fauna of the three continents of the Northern Hemisphere as residues of the Tertiary life brought southward from the Arctic regions with the glacial invasions. He recognizes two distinct regions of plains; one the inner-Asiatic steppes, and the other designated as the sonoral, in America. The four major wooded regions, namely the European-West-Asiatic, the Manchurian-Siberian, the American-Pacific, and the New-England-Canadian, he finds more closely related to each other. The formation of the present topography and vegetable and animal life of the arctic tundras he places in the Pliocene. Hofmann's statistical method of comparison of numbers of species from the same origin in the various regions, combined with an historical study of the movement of the ice-fields, were utilized in this study. A bibliography and author and subject indices are provided.

JOUANNET. *Grand-Père de la Préhistoire.*

By André Cheynier. Imp. Chastrusse, Praudel et Cie, Brive. 15 francs. 10 x 6½; 101 + 3 plates; 1936 (paper).

In this little book Doctor Cheynier fulfils the pious task of rescuing from undeserved oblivion an archeologist who in the generation before Boucher de Pesthes began his work had discovered and described a rich neolithic station with its pottery, polished axes and arrow heads; had discovered caves inhabited by paleolithic man; had recorded the association of fossil bones with chipped flints; had made experiments on the chipping of flints; had classed ancient times into ages of stone, of bronze and of iron; had divided the stone age into two periods; had demonstrated the origin of bronze axes in those of polished stone, and of bronze daggers in those of chipped stone; had discovered the first station of the Solutrean period; and had had chemical analyses made of fossil bones and of the bronze of the ancient axes. The book includes a biographical sketch of Jouannet, a reproduction of his works on prehistory and a bibliography of his writings.

GENETICS

GRUNDZÜGE DER VERERBUNGSLEHRE.

By Friedrich Alverdes. S. Hirzel, Leipzig. 5 marks. 8½ x 5¾; viii + 143; 1935 (paper).

A clear and thorough introduction to genetics is here presented, in easy style. Three general chapters cover such topics as cells, cell division, multicellular organization, fertilization, continuity of the germ-plasm, somatoplasm, nature and nurture, definitions of race and species, etc. Four chapters on Mendelism complete almost half of the book. Further chapters are devoted to heredity and sex, variation of phenotypes, of genotypes, mutations, multiple factors. Two final chapters concern human heredity, with remarks on twinning. The rôle of environment is considered, but not in detail. The discussion is always generous and a large number of practical examples are cited for the main topics; but many

important topics are omitted, particularly those of recent acceptance. Forty-five diagrams and sketches of cells are included, also a 6-page index.

INHERITANCE AND EVOLUTION.

By W. F. Wheeler. With a Foreword by E. B. Ford. Methuen and Co., London. 3s. $7\frac{3}{8}$ x $4\frac{3}{4}$; xii + 116; 1936.

This is a brief but well-written summary of the relation of cytology to genetics; of the operation of Mendel's laws and their subsequent consequences; and of the rôle of inheritance in evolution. The material is essentially comparable to that studied by the college sophomore but has the virtue of a certain up-to-dateness and accuracy frequently lacking in general biological texts. Each chapter contains a short bibliography and the book boasts an adequate index and glossary. There are a few well-chosen diagrams in the text that aid in understanding the discussions. The book should prove useful to students wishing to review their elementary genetics and to the intelligent layman desiring orientation about heredity and its general significance.

PROBLEMS IN HUMAN HEREDITY. (*Learning by Thinking.*)

By Vincent W. Jackson. Vincent W. Jackson, University of Manitoba, Winnipeg, Canada. 50 cents. 10 x $6\frac{3}{4}$; 48; 1937 (paper).

A laboratory outline of genetics and eugenics with brief explanations and diagrams and numerous questions for the student to solve or discuss.

GENERAL BIOLOGY

TRAVAUX DE LA STATION BIOLOGIQUE DE SÉBASTOPOL, *Tome V*. Containing the following articles: *Beobachtungen über die pelagischen Eier der Fische des Schwarzen Meeres*, by W. Vodjanitzki; *Essai d'une Évaluation quantitative de la Végétation du Fond de la Mer Noire*, by N. Morosova-Vodjanitzkaja; *Phytobenthos des Karkinitzky Busens*, by N. Morosova-Vodjanitzkaja; *Die Algen der Umgebung der Biologischen Station Karadag*, by N. Morosova-Vodjanitzkaja; *Some data concerning the Development of Delphinus delphis L.*, by E. N. Malm and K. T. Trotzkaya; *De l'Origine bactérienne du Pigment rouge de l'Amphioxus lanceolatum, Cause de sa Mort et Destruction*, by J. Ravitch-Stcherbo; *A Review of the European Species of the Genus Trigla (Pisces, Triglidae)*, by A. N. Svetovidov.

Academy of Sciences SSSR, Moscow and Leningrad. $9\frac{3}{4}$ x $6\frac{1}{2}$; 349; 1936.

The first paper in this collection of contributions to the marine biology of the Black Sea is a study of about forty species of pelagic eggs including several not hitherto described. The second paper gives a quantitative evaluation of the vegetation on the bottom of the Sea, with a discussion of the seasonal changes and adaptation. This is the longest paper of the lot (175 pages). Fifty-five species of macrophytes and their relative densities in the Karkinitsky Bay are the subject of the third paper. The fourth article presents quantitative studies of the algae found on five different types of sea-bottom in the region of Karadag—gravel, rocks and stones of volcanic origin, rocks and stones of sedimentary origin, sea-sand, and sand and slime brought in from rivers. The development of *Delphinus delphis* L., one of the most widely distributed species of this sea, during foetal life and the first six months of post-natal life is the subject of the fifth paper. In the sixth study it was found that the red pigmentations that are produced by bacilli and cause the death of *Amphioxus lanceolatum* in aquaria were not observed on bacilli infested catches from the sea, and it was therefore concluded that these bacilli are only pathogenic under artificial conditions. The last paper describes seven species of *Trigla* found in the Mediterranean Sea. Three of these have also been observed as migrants in the Black Sea.

The papers are in Russian, with English, French or German summaries as indicated in the title above.

BIOLOGY. *A Study of the Principles of Life for the College Student.*

By U. A. Hauber with the collaboration of

M. Ellen O'Hanlon. F. S. Crofts and Co., New York. $3.90. 9 x 6; xii + 559; 1937.

The present trend in the teaching of biology is away from the technical and toward the cultural aspect of training for a scientific or professional career. In the preparation of this new text, the authors have very clearly and successfully emphasized this trend.

The course is built around the important biological principles rather than on the study of types, although due emphasis is placed on the fact that a principle may become a mere memorized formula unless the student himself observes its manifestations in a concrete organism. The book is designed primarily for a full year course for college freshmen with the assumption that laboratory work will be included. The many drawings and diagrams, the extensive glossary, the table of contents and the complete index will find favor with the student who is embarking on his first course in college biology.

PICTURING MIRACLES OF PLANT AND ANIMAL LIFE.

By Arthur C. Pillsbury. J. B. Lippincott Co., Philadelphia. $3.00. 8¼ x 5½; 236; 1937.

Author Pillsbury is a professional photographer who became interested in biology as a result of trying to take action pictures of the side of a very sedentary mountain—at least so he says. It was for this purpose that he first developed the lapse-time motion picture camera to photograph the beautiful movement of shadows of clouds on a cliff of the Sierras in Yosemite National Park. Having developed the technique, he used it to speed up the opening of a rose with such good results that he has been taking motion pictures of slow plant and animal movements ever since. His present book is written in the style of an amateur bubbling over with enthusiasm for his favorite hobby and the spirit is readily transmitted to the reader. There is little technical description, the text being mainly a series of adventure stories with the author bragging pleasantly about his many accomplishments. He does tell in sufficient detail how each of his experiments may be repeated but unfortunately for those who would like to take up the sport themselves, the equipment costs anywhere from $1,000 up. His chapter on soil-less "chemical farming" by which 2,465 bushels of potatoes may be raised per acre is fascinating and sounds much more hopeful as a prospective hobby for even a city dweller, as little space is required and the necessary ingredients may be had for a dollar or less.

PLANKTONKUNDE FÜR JEDERMANN. *Eine erste methodische Einführung für den praktisch arbeitenden Hydrobiologen. Handbücher für die praktische naturwissenschaftliche Arbeit Band 26.*

By Willy Baumeister. Franckh'sche Verlagshandlung, Stuttgart. RM. 2.80 (in Germany); RM. 2.10 (outside of Germany). 10 x 7; 62; 1936.

Here we have a complete introduction to the study of the plankton. From it we may learn how to collect and observe living plankton; how to prepare specimens for microscopic study; how to use and care for the microscope and something about microscopic photography; and how to identify some of the commoner kinds of freshwater plankton of both kingdoms. There is also a chapter on freshwater plankton ecology in which twenty different kinds of environment are discussed. Perhaps to some this part of the work will seem too detailed, for there is a distinction drawn between fish ponds and goose ponds; and even roof gutters, burial vaults, and flax retting vats come in for their share of attention. The illustrations leave nothing to be desired, and there is an index of four pages and a bibliography of three. It is unfortunate that books similar to this are not produced on this continent.

HYDROGRAPHY OF MONTEREY BAY, CALIFORNIA. THERMAL CONDITIONS, 1929–1933. *Transactions of the American Philosophical Society. New Series, Volume XXIX.*

By Tage Skogsberg. University of Pennsylvania Press, Philadelphia. $3.00. 12 x 9¼; 152; 1936 (paper).

From the point of view of hydrography, the Monterey Bay region had been practically unexplored until this survey was started in 1929. This report, largely descriptive, is concerned with the first five years' survey of the thermal conditions. While all of the data obtained during the period has been analyzed, only a limited portion of the findings are presented at this time. (The original data are available at the Hopkins Marine Station, Pacific Grove, to those especially interested.) Sufficient tabular matter has been included, however, so that together with the 45 figures (graphs, map outlines, etc.) the reader obtains a clear and interesting picture of the five years' work.

PHILOSOPHIE DER NATURWISSENSCHAFTEN. *By Max Hartmann. Julius Springer, Berlin.* RM. 3.60. 10 x 6½; 46; 1937 (paper).

This is a reprint, with a few annotations and a bibliography added, of an article published in a *Festschrift* in celebration of the twenty-fifth anniversary of the *Kaiser Wilhelm Gesellschaft zur Förderung der Wissenschaften.* The fundamental theme is that "in spite of all the differences between physics and biology, the same philosophical bases underly both, and the same methods of research are practicable."

URDEUTSCHLAND. *Deutschlands Naturschutzgebiete in Wort und Bild. Lieferungen 24.*

By Walther Schoenichen. J. Neumann, Neudamm. 2.50 marks. 10¾ x 8¼; 281–342 + 8 plates; 1937 (paper).

This is the last number of Volume II of the carefully written and beautifully illustrated work on the natural history of Germany. Notices of previous numbers have appeared in this REVIEW from time to time. The present number describes the more rare and beautiful flowers and birds native to Germany.

HUMAN BIOLOGY

AFTERMATH: *A Supplement to The Golden Bough.*

By Sir James G. Frazer. The Macmillan Company, New York. $3.00. 8½ x 5½; xx + 494; 1937.

So the literature of cultural anthropology grows new data on magic and its related subjects accumulate. Instead, however, of issuing a new edition of *The Golden Bough* Sir James Frazer has gathered this new material into a supplementary volume. On the whole he finds that the new data support the conclusions that he had already drawn.

> But now, as always, I hold all my theories very lightly, and am ever ready to modify or abandon them in the light of new evidence. If my writings should survive the writer, they will do so, I believe, less for the sake of the theories which they propound than for the sake of the facts which they record. They will live, if they live at all, as a picture or moving panorama of the vanished life of primitive man all over the world, from the Tropics to the Poles, groping and stumbling through the mists of ignorance and superstition in the eternal search after goodness and truth. When I first put pen to paper to write *The Golden Bough* I had no conception of the magnitude of the voyage on which I was embarking; I thought only to explain a single rule of an ancient Italian priesthood. But insensibly I was led on, step by step, into surveying, as from some specular height, some Pisgah of the mind, a great part of the human race; I was beguiled, as by some subtle enchanter, into inditing what I cannot but regard as a dark, a tragic chronicle of human error and folly, of fruitless endeavour, wasted time, and blighted hopes. At the best the chronicle may serve as a warning, as a sort of Ariadne's thread, to help the forlorn wayfarer to shun some of the snares and pitfalls into which his fellows have fallen before him in the labyrinth of life. Such as it is, with all its shortcomings, I now submit *The Golden Bough* in its completed form to the judgment of my contemporaries, and perhaps of posterity.

INTERRACIAL MARRIAGE IN HAWAII. *A Study of the Mutually Conditioned Processes of Acculturation and Amalgamation.*

By Romanzo Adams. The Macmillan Co., New York. $4.00. 8½ x 5¾; xvii + 353 + 11 plates; 1937.

No less than eleven racial classes of significant numerical proportions besides a group of a few hundred Negroes are distinguished in the census of Hawaii's population of about 350,000 people. These include whites of several nationalities,

some of whom have Negro and American Indian blood, Hawaiians, Filipinos, Chinese, Koreans, and Japanese, the latter being by far the most numerous. The greatest amount of racial mixture has taken place between the native Hawaiians and other groups, usually from marriages between Hawaiian women and foreign men, there being approximately 22,600 Caucasian-Hawaiians and 15,600 Asiatic-Hawaiians on the islands today. The latter are mostly Chinese-Hawaiian mixtures, the Japanese out-marrying less than the other groups. But all sorts of other combinations also occur. When the whites first discovered the islands, a number of sailors married native women of chiefly class, were accepted into the upper class, and their mixed breed children inherited large estates and in consequence high position from their mothers. As a result, for many years there was no social stigma attached to miscegenation, which was practiced freely as a result of the fact that the immigrant laborers who later arrived in large numbers brought very few women of their own race with them. The relative absence of sensitiveness on account of mixed blood makes it quite easy to collect data on the ancestry of individuals and as immigration has now almost stopped the islands are an almost perfect place to study the physiological, intellectual, and sociological effects of nearly every conceivable type of racial mixture. Mr. Adams has done a remarkably wonderful piece of work in analyzing the situation. The status of each important type of mixed and "pure" group is discussed from the standpoint of social-economic position, attitudes of the group, and attitudes of other groups toward it. In general, he finds that the hybrid individual is apt to be intermediate in every respect between the two races from which he comes.

MOSLEM WOMEN ENTER A NEW WORLD. *Publications of the American University of Beirut Social Science Series No. 14.*

By Ruth F. Woodsmall. Round Table Press, Inc., New York. $3.00. 8½ x 5½; 432 + 30 plates + 1 folding map; 1936.

This is an extraordinarily interesting book, that will serve as a useful source to sociologists and human biologists wanting to know what is going on in the Moslem world so rapidly changing today. The author is General Secretary of the World Y.W.C.A. Nine years' experience in Y.W.C.A. work in the Near East after the War gave her a solid background of experience upon which to build her treatise. She gathered her material for the book while holding a Traveling Fellowship of the Rockefeller Foundation. She proves herself to be a careful and acute observer. There is occurring now in Egypt, Palestine, Syria, Trans-Jordan, Turkey, Iraq, Iran, and India a social change of the greatest significance so far as concerns Moslem women. They are being rapidly freed of the crushing restrictions that have overwhelmed them for ages past. Educational facilities for women are everywhere developing, the old collective type of family life is being replaced by the individual home, polygamy is on the way out, and generally *incipit vita nova.*

The chief defect of the book is in the diffuseness of its style. There seems to be something in the conditioning and training of social workers that almost invariably makes them a bit on the gabby side when their efforts reach the stage of exposition. The kernel tends to hide itself in too thick a verbal husk. But in Miss Woodsmall's case the enormous interest of her material brings forgiveness for the sin of loquacity.

There is an adequate index, and a route map of her travels.

THE SOCIAL CONSEQUENCES OF THE ECONOMIC DEPRESSION. *Studies and Reports Series C (Employment and Unemployment) No. 21.*

By Wladimir Woytinsky. International Labour Office (Washington Branch), Washington, D. C. $2.00. 9½ x 6¼; xi + 364; 1936 (paper).

This study, based on official statistics of prices, unemployment, production, etc., describes the course of the economic depression and how it has affected industry, commerce and agriculture, industrial and agricultural countries, and the different economic classes of people. The high de-

gree of interdependence between countries and between the different economic classes of the same country is considered the most important element in the diffusion of the crisis. Thus, while conditions in industry were the immediate cause of the depression, agriculture was affected almost at once. Similarly, agricultural countries have borne a good portion of the loss sustained by the industrial nations, and in each country the net result of the economic crisis has been a general lowering of the standards of living. What classes have lost most because of the depression? Not the capitalists, nor the farmers, nor the small business men, but instead, the laboring classes and persons with small fixed incomes. In the author's opinion, since contraction of industrial production was the principal factor of this crisis, the means used by the governments to alleviate conditions have been in general useless because they have been mostly directed to aid agriculture. As he sees it, all efforts should have been made to increase industrial production. Notwithstanding the obvious limitations of the material, the author is able to draw conclusions consistent with well established facts. They are of interest and should serve as a starting point for further research.

MARRIAGE CONDITIONS IN A PALESTINIAN VILLAGE, II. *Societas Scientiarum Fennica. Commentationes Humanarum Litterarum, Tomus VI, Nr. 8.*

By Hilma Granquist. Akademische Buchhandlung, Helsingfors; Otto Harrassowitz, Leipzig. RM. 9.60. 9¼ x 6½; 366; 1935 (paper).

The author lived for some time in the Mohammedan village of Artas in Palestine. There she noted the customs of the people and having acquired friends among the natives is able to interpret her findings with unusual clearness and authority.

In this volume, the second of a series, the author describes the procedures of betrothal, the preparations and the festivals preceding a wedding, the marriage contract and ceremony. In the second part of the book she discusses the rights and obligations of the marital partners with regard to themselves and to their respective families; the position of the wife in cases of monogamous and polygamous marriages; problems of separation and divorce; and the status of the widowed. Illustrative cases are reported in detail. There is an extensive bibliography and the author also compares her observations with the reported customs of other villages and localities in Palestine.

This is without doubt a first-class ethnological study and should prove of interest to all biologists, whatever their specialty. The descriptions clearly show the fundamental similarities of certain patterns of human social behavior. For example, the threat: "I am going home to mother" (substitute father or brother for mother) is apparently just as effectively and frequently made by the Mohammedan bride as by her Christian sister.

THE BIOLOGICAL BACKGROUND OF HUMAN POPULATION THEORY.

By F. S. Bodenheimer. Palestine. 9 x 6; 157; 1936. [In Hebrew].

This volume on human population theory by the distinguished Professor of Biology in the University of Jerusalem merits translation into a more generally accessible language than Hebrew. It opens with a general introduction into the problems and achievements in the field of infra-human animal population theory, experimentation, and observation. It then summarizes and discusses the influence of environmental factors upon human beings, as individuals and as group civilizations. The work of Pearl on the problems of population, human and experimental, is then described at some length, and, following that author's lead, the data of the biology of sex and reproduction are brought into direct relationship to population problems and theories.

The latter half of the book is devoted to such matters as the criticism of Malthus's position from the viewpoint of the biologist and critical student of modern methods of population limitation; business cycles as viewed by the animal ecologist; and finally the problems of modern eugenics and "nature and nurture" in human life.

There is a short but well-selected bibliography, but no index.

A first-rate contribution.

MEN, MEDICINE AND FOOD IN THE U.S.S.R. *By F. Le Gros Clark and L. Noel Brinton. Lawrence and Wishart, London.* 5s. net. $7\frac{1}{4}$ x $4\frac{7}{8}$; v + 173; 1936.

This book we highly recommend to such of our readers as wish to get an objective picture of the life of the Russian people today, and what biologist does not? The authors are sympathetic, and even in some degree enthusiastic about the aims of the Soviet leaders. This occasionally, but only occasionally, leads them to make absurd statements, such as that "the Soviet system has at last brought to birth the science of preventive medicine." But in general the book is a calm and dispassionate account of what the authors (one of whom speaks Russian) found out regarding the sort of things the biologist would like to know about—food, health, the practical details of the organization of scientific work in a country where people and state have a deep and pervasive respect for science. A basic article of faith in their social philosophy is that "Science will mould the world into a place worthy of human habitation and will mould and remould it again past all our present imaginings. It will also fashion a humanity worthy of the new world. Thus the scientist today, as scientist, embodies to him the sound wisdom that is to set mankind upon the fresh path of development."

The book has a short bibliography, and is well indexed.

RECOLLECTIONS AND REFLECTIONS. *By Sir J. J. Thomson. The Macmillan Company, New York.* $4.00. $9\frac{1}{4}$ x $5\frac{3}{4}$; viii + 451; 1937.

One of the most interesting parts of this book is the series of character sketches of the scholars and research men with whom the great physicist came into contact during his student days in England, and later in the course of his long and distinguished career. Entertaining accounts are given of the undergraduate life at Cambridge; the activities of research students, and of the organization of the university research laboratories; "J.J.'s" work with the British government during the World War; and of his first visits to Canada and to the United States. The author has relatively little to say about American universities, but does have an amusing passage about Baltimore hospitality and the evident pleasure of life and living there generally.

The last quarter of the volume is a description of the fundamental researches in the Cavendish laboratory, over a long span of years, on electronic waves, röntgen rays, electrolytic dissociation, the theory of light, relativity, etc. An impressive list of Cavendish students who have become Fellows of the Royal Society has been added. There are name and subject indices.

THE EARTH GODDESS. *A Study of Native Farming on the West African Coast. Royal Empire Society Imperial Studies, No. 12. By G. Howard Jones. Longmans, Green and Co., New York and London.* $5.00. $8\frac{5}{8}$ x $5\frac{1}{2}$; vii + 205 + 8 plates; 1936.

It is high time in the opinion of the author that some thought should be given to the future of agriculture on the West African Coast—a strip of land about a hundred and fifty miles broad stretching from the western seaboard of Sierra Leone to the eastern boundary of the Cameroons.

Deep religious convictions and tribal customs of the natives of the region together with a climate not well suited to the white man have hampered the European in inaugurating his more highly approved systems of agriculture. Changes must be wrought however as the demand for exports increases, and the author who has had years of experience and of study in the field of agriculture in Africa and in Europe believes that the most favorable line of development lies in some system of coöperative farming. He has arrived at his conclusions painstakingly, taking into consideration the temperament of the natives and the dangers of a social upheaval likely to follow in the wake of any drastic move.

THE KEY TO SWEDEN.

By Serge de Chessin. Translated from the French by Alice S. von Holstein. Fritzes, Stockholm. Kr. 6. 8⅜ x 5½; 233 + 10 plates; 1936 (paper).

"Mounted on a wild goose" one flies quickly over Sweden in the first chapter, catching delightful glimpses of the varied life and country-side of this picturesque land. After the goose ride we are turned loose to get a closer and more intimate view of the character, lives, customs and institutions of this stalwart blond race, but always we have our guide—the author—along with us who interprets for us many of the things we might prefer to interpret for ourselves. We might doubtless in the end come to many of the same conclusions concerning this wonderful country and her superior people, but still it would have been more fun to poke around a bit and get views of the same things occasionally from different angles; for it is always from the spiritual heights that our interpreter speaks and his head is always in the clouds as far as Sweden is concerned. But in spite of this *The Key to Sweden* is well worth reading. The Swedish people are seen in their homes, in their schools, at work and at play, and one gains some idea of their national politics and foreign policy.

INTO THIS UNIVERSE. *The Story of Human Birth.*

By Alan F. Guttmacher. The Viking Press, New York. $2.75. 8½ x 5¾; x + 366 + 14 plates; 1937.

This book, written by an obstetrician, is an authoritative and interesting account of human birth. It includes the lore of childbirth through the ages, the prenatal months, and the modern scientific practices.

The contents were suggested to the author by the ignorance of patients, students and laymen. Since these groups comprise the audience for whom the book was written, one apparent criticism presents itself: undue emphasis upon the abnormalities of pregnancy and labor. The author realizes this and attempts to forestall such criticism by stating in the epilogue: "It (the book) does not omit the detailed story of the normal uncomplicated case, but in the telling it may seem only one case among many." Nevertheless, the original impression lingers and the book, while suitable for the enlightenment of students and laymen might well prove upsetting to an obstetrician's patients.

Drawings and a few photographs illustrate the text and, in addition, there is a list of recommended reading. There is also an index.

THE DOCTRINE OF SURVIVALS. *A Chapter in the History of Scientific Method in the Study of Man.*

By Margaret T. Hodgen. Allenson and Co., London. 5s. net. 7¾ x 5; 192; 1936.

This volume, based on the British sources of the doctrine of survivals, concerns itself with cultural persistence, or the process of tradition. Many of the problems dealt with are older than history itself, but the author's method is new, and her style is fresh and stimulating. From the thorough discussion of "Developmentalism", we are brought face to face with the fact that typical histories of scientific development tend to be anecdotal or biographical, and that the *method* by which science advances is discussed only quite infrequently. Furthermore, the few times that it is discussed, it is left not to the scientist or the historian, but to the logician.

The author has made no attempt to give a complete account of the changes in the scientific method in the study of man, but rather has developed the history of the concept as such, together with its use by nineteenth century developmentalists. She has incorporated into the present volume many bibliographic lists which should stimulate workers in the field to further discussion and investigation.

MISCEGENATION. *A Study of the Biological Sources of Inheritance of the South African European Population.*

By George Findlay. I. L. van Schaik, Pretoria, South Africa. 1s. 6d. 8½ x 5¼; 48, 1936 (paper).

Postulating that purity of white blood is essential to the future of European civilization in South Africa, this pamphlet dis-

cusses the "bridge" by which negroid blood trickles into and progressively dilutes the white. This bridge consists of the half-breeds, from among whom individuals of lighter color and more European-like features are able to "pass" for whites. Since the bridge receives contributions from both races, miscegenation proceeds despite the virtual cessation of primary crossing.

Although the author admits that passers-for-white (called "escapers") include persons who "shine in the professions, in science, in the political world and in society generally" (p. 47), he considers miscegenation a biological evil, which he would like to have remedied. No criticism is made of society's custom of stigmatising persons because of racial origin.

NAVEN. *A Survey of the Problems suggested by a Composite Picture of the Culture of a New Guinea Tribe drawn from Three Points of View. By Gregory Bateson. University Press, Cambridge; The Macmillan Co., New York.* $5.00. 8½ x 5½; xx + 286 + 29 plates; 1937.

This book discusses the customs of the Iatmul tribes of New Guinea. The Naven ceremony in which men caricature women is described in great detail and its relationship to the culture and ethos of the Iatmul as a whole is analyzed. The author is attempting a new technique of studying a culture. He points out that if every aspect is thoroughly understood no single detail appears bizarre or strange. "The emotional background is causally active within a culture, and no functional study can ever be reasonably complete unless it links up the structure and pragmatic working of the culture with its emotional tone or ethos."

There are many excellent photographs, and a glossary of technical and native words which is most valuable because of the author's predilection for polysyllabic and sonorous terms.

SUBSTITUTE PARENTS. *A Study of Foster Families. By Mary B. Sayles. The Commonwealth Fund, New York; Oxford University Press, London.* $1.75. 9 x 6; vii + 309; 1936.

The first part of this book is devoted to a discussion of some of the factors involved in the motives leading to the adoption of children and of the knowledge that foster parents should have of themselves and of the child to be adopted. The author has devoted the major portion of her work however to a study of several cases in which the placing of the children in foster homes has turned out successfully. The study is concerned primarily with those less fortunate youngsters "who have been passed from hand to hand and thus have never had a chance to be unaware that they are separated from their own parents." Most of the cases presented real problems and the author has endeavored to bring into relief those qualities of the foster parents which seem largely responsible for the success of these undertakings.

CREATIVE EDUCATION AND THE FUTURE. *By Olive A. Wheeler. University of London Press, London.* 8s. 6d. net. 7⅝ x 5¼; xi + 365; 1936.

In this book the author has evolved a philosophy of education by applying recent biological and psychological discoveries to educational needs. The problem has been treated from three points of view: (1) General view of the *living present*. (2) The nature of individual development and the chief varieties of individuals for whom educational provision should be made. (3) The living present in relationship to the facts collected.

Separate chapters have been devoted to science, social life, religion and ethics, etc. and show how modern development in each field needs greater emphasis on first-hand knowledge. The book is well written and the author shows a competent knowledge of the subject. In general, the emphasis has been placed upon the psychological aspect. There is an index.

L'ESPÈCE HUMAINE. *Encyclopédie Française, Tome VII.*

Edited by Paul Rivet. Comité de l'Encyclopédie Française Éditeur, 13 rue de Four, Paris. 110 francs. $11\frac{5}{8}$ x $9\frac{3}{4}$; 618; 1936.

This being a volume of an encyclopedia, an attempt is made to answer any and all questions which might be looked up under this heading; that is, on the subjects of Anthropology, Ethnography, and Ethnology. Part one discusses the social organization, tools, and means of subsistence in primitive societies and gives more or less detailed accounts of most of the peoples on the earth today. Part two deals with the problem of classification and distinguishing between races, and also presents some account of human inheritance. The third and last part covers distribution and density of population and vital statistics. An extensive classified bibliography and list of journals, and a good index are included. The illustrations which are numerous and excellent are devoted mainly to photographs of typical individuals of all races and groups.

An excellent reference source.

LA DESTINÉE HUMAINE.

By Charles Nicolle. Librairie Félix Alcan, Paris. 1.20 francs. $7\frac{3}{8}$ x $4\frac{3}{4}$; vii + 98; 1936 (paper).

This book by the Director of the Institut Pasteur of Tunis is of interest, not only for the questions that it examines, but as a chapter in the natural history of a biologist. In it Professor Nicolle returns to the questions with which he dealt in *la Nature*. Our reason he concludes, is highly efficient in its performance of the task for which it was developed, the adjustment of the organism to its environment, but ill adapted to deal with more remote questions, such as survival after death. However, since this hypothesis is as incapable of disproof as of proof, he counsels his readers to rejoin the church of their upbringing if they will be rendered easier in spirit thereby. A final note informs us that the author followed his own advice soon after writing the book.

A WOMAN SURGEON, *The Life and Work of Rosalie Slaughter Morton.*

By Rosalie S. Morton, Frederick A. Stokes Co., New York. $3.00. $8\frac{5}{8}$ x $5\frac{3}{4}$; xiv + 399; 1937.

Against the wishes of her family Rosalie Slaughter left a comfortable Virginia home to enter medical school and begin an adventurous life that led her to many lands—among them Germany, France, India, Laborador and Serbia. During that time she was privileged to meet many celebrities, both professional men and writers. Perhaps it is due to her Quaker modesty, but nevertheless we find it disappointing that Mrs. Morton did not tell us more of her medical work, and less about the doings of the great.

One is rather amazed at the versatility and energy of this woman. Besides her work as a surgeon she founded the American Women's Hospitals during the world war, and after the war undertook to educate sixty Serbians in American colleges and universities.

THE SOCIAL THOUGHT OF THE ANCIENT CIVILIZATIONS.

By Joyce O. Hertzler. McGraw-Hill Book Co., New York. $4.00. 9 x 6; xvi + 409; 1936.

Although the systematic discussion of social phenomena begins with the Greeks, the laws, proverbs and ethico-religious writings of the pre-Greek civilizations contain material with which the historian of social thought must reckon. Many of the ethico-religious writings are tantalizingly vague, such as the Zoroastrian formula, "Good thoughts, good words, good deeds," without much specification as to what thoughts, words and deeds are good. And when the writings are more specific, the approved acts and qualities of one civilization are not always the same as those of another. However, beneath these differences there are important agreements. The most widespread of all social behavior formulas is the golden rule, which is found in Egyptian, Babylonian, Hindu, Persian and Chinese literature.

MAJOR NOAH. *American-Jewish Pioneer.*

By Isaac Goldberg. Alfred A. Knopf, New

York. $3.00. 8½ x 5¾; xvii + 316; 1937.

The subject of this biography, Mordecai Manuel Noah (1785–1851), had a finger in many pies. He was American consul at Tunis, sachem of the Tammany Society, sheriff, surveyor of the port and associate judge of the Court of Sessions of New York City, editor of various newspapers and a successful playwright. Besides these multifarious activities he found time to project a city of refuge for the Jews on Grand Island in the Niagara River, a city the development of which was incidentally to pay a handsome profit to Major Noah himself. The project got as far as the dedication, with much ceremony, of a corner stone for the intended city, but strangely enough Jewry did not show that eagerness to embark on a new exodus into the wilderness which Major Noah had anticipated.

CONTRIBUTIONS TO THE ETHNOGRAPHY OF THE KUTCHIN. *Yale University Publications in Anthropology Number 14.*

By Cornelius Osgood. Yale University Press, New Haven; Oxford University Press, London. $2.50. 9¾ x 7; 190 + 10 plates; 1936 (paper).

The Kutchin Indians, (consisting of eight tribes inhabiting the area around the great bend of the Yukon and eastward into the valley of the Mackenzie) are sufficiently distinguished from their neighbors in physique, culture, and language that the author considers that they merit the name, a nation. In this survey there are presented

> various aspects of Kutchin culture with the plan of drawing in a purely descriptive way a picture of aboriginal Kutchin customs at the period just previous to permanent European contact. My purpose is to provide a background which I consider necessary for a logical continuation of cultural studies based on the Northern Athapaskan tribes—.

The study includes numerous illustrations, a tabulation of aboriginal Kutchin cultural traits and a bibliography.

TWENTY-FOURTH ANNUAL REPORT OF THE SECRETARY OF LABOR *for the Fiscal Year Ended June 30, 1936.*

Government Printing Office, Washington. 15 cents. 9¼ x 5¾; vii + 150; 1936 (paper).

There are included reports on the employment situation and on the activities of the U. S. Employment Service, the strikes in different sections of the country, labor legislation, social security, immigration, etc. Tables containing a detailed classification of the funds spent by the various departments are given. The services rendered to the public are described, as well as the research work now in progress.

PORTUGAL: *A Book of Folk-Ways.*

By Rodney Gallop. University Press, Cambridge; The Macmillan Co., New York. $5.50. 8½ x 5½; xv + 291 + 17 plates; 1936.

This is a charming account of Portuguese folk lore. The author describes the different parts of the country, the traditional beliefs and customs, the music and the literature. The mixture of pagan superstitions with Christian beliefs and their relation to the calendar is well brought out. The book is beautifully illustrated with photographs and drawings; there is an extensive bibliography and an index.

TRUTH OF A HOPI AND OTHER CLAN STORIES OF SHUNG-OPOVI. *Museum of Northern Arizona Bulletin No. 8.*

By Edmund Nequatewa. Edited by Mary-Russell F. Colton. Northern Arizona Society of Science and Art, Flagstaff, Ariz. $1.75. 8¼ x 5¼; 114; 1936.

This is a collection of legends of the Hopi clans. The original style seems to have been retained and they contain both history and mythology. There are many valuable and informatory footnotes and a bibliography.

ZOÖLOGY

THE SCIENCE OF ANIMAL LIFE.

By Arthur W. Lindsey. Harcourt, Brace and Co., New York. $3.75. 8½ x 5⅝; xi + 656; 1937.

"Of the making of many books there is no

end." This quotation appears to have been in the mind of the author when he penned his preface, for he begins with the observation that a new book on an old subject can be justified only if the author believes that he has something new to offer the reader.

To the present reviewer it appears very definitely that the author has something new to offer. In the first place he has a literary style of such refreshing spontaneity that it is likely to hold the attention of even the casual reader to the end, and if he happens not to be a biologist, he is not unlikely to become one.

In the second place, the field of biology is now so wide that anyone attempting to deal with it in a single volume is likely to find the problem of what to omit greater than that of what to include. In the present instance excellent judgment has been used. The book is divided into sections as follows: The Foundations of Life; Organization and Classification of Animals; The Maintenance of the Individual; The Maintenance of the Species; Problems of Origin; and Biology and Human Life. These subjects are not equivalent in importance, hence the sections dealing with them are not of equal length, but they are well proportioned to each other, and together they give us not only a composite picture of the entire field of animal biology as it exists today, but also a summary of the important contributions to biological thought of the past from Hippocrates to T. H. Morgan.

In the section entitled Problems of Origin the author abandons the better known paths of *sensu stricto* science to explore the less familiar trails of cosmic philosophy, but here he seems somewhat less at home. For instance, in discussing the theory that life came to the earth from inter-stellar space (a theory for which we are indebted chiefly to Arrhenius, although his name does not appear in the text) the author states that the theory is practically valueless, "for if life came to the earth already formed its origin elsewhere remains to be explained." This, of course, is a *lapsus calami*, for if life exists elsewhere than on the earth there is no more reason to feel obliged to account for its origin from a lifeless source than there is to account for the origin of energy or of matter—all three may have coexisted since the morning stars sang together.

There is an ample index of thirty-six finely printed pages.

HANDBOOK FOR SHELL COLLECTORS. *Illustrations and Descriptions of 2,200 Species of Mollusca. Fourth Edition.*

By Walter F. Webb. Walter F. Webb, 202 Westminster Road, Rochester, N. Y. $2.50. 9¼ x 6; 291; 1936.

The compiler of this work is a well known dealer in natural history material who has devoted no small part of his life to arousing enthusiasm for collecting. With the exception of minerals, shells are the most satisfactory material for the beginner, since they deteriorate less rapidly than bird's eggs, flowers, insects, etc., and therefore require less care. For this reason the bulk of the book is devoted to shells, though lower forms of life are not neglected.

In order to assist the beginner to identify his material Mr. Webb has collected numerous illustrations from various sources, many of them works now out of print, and has supplied a few lines of comment to accompany each one. Space at the bottom of each column that would otherwise be vacant is filled with miscellaneous observations that add to the general interest of the work.

In certain instances where the rules of the International Commission necessitate the use of unfamiliar names in place of others that have enjoyed almost universal usage, the compiler has used both names, putting the more familiar one in parentheses between the correct generic and specific term. This is unfortunate, as the commission has ruled that only subgeneric names shall be so treated. The correct way to cite a familiar name in addition to the correct one is to use the complete binomial form and place it in parentheses after the correct specific name. Departure from this practice is likely to augment the confusion, rather than diminish it. The book also shows evidence of inadequate proof reading, many pages affording examples of "printer's spelling."

Notwithstanding these defects the book will be found very helpful both to beginners and to those who are not beginners even. Most of the shells illustrated come from the coasts of North America, but a generous proportion of highly colored and bizarre shaped "mantel-piece" shells from the tropics are included. The index covers twenty-four pages, and includes popular as well as scientific terms.

BIRDS AROUND THE YEAR.
By Lorine L. Butler. D. Appleton-Century Co., New York. $2.00. 7½ x 5¼; xi + 242 + 8 plates; 1937.

BIRD BEHAVIOUR. *A Contribution Based Chiefly on a Study of the Black-Headed Gull.*
By F. B. Kirkman. T. Nelson and Sons, London. 7s. 6d. 8¾ x 6; xv + 232; 1937.

Birds Around the Year is a pleasant little volume designed to interest and entertain the bird-lover and amateur ornithologist by stressing the seasonal aspects of bird distribution and behavior. The discussions are presented in a popularized style and no attempt has been made to develop theoretical or technical matters. The material is, nevertheless, authoritative and gives evidence of having been judiciously selected. The book is essentially a natural history account in that the mating, nesting, feeding and migrating behavior of common birds is discussed relative to their seasonal abundance. To the distress of the reviewer the author frequently deserts prose for verse. This is so often true in books of this type that we, as hard-boiled cynics, are tempted to suggest that some bright young person prepare a doctorate on the stimulus given poetry by ornithology (or *vice-versa*). Indubitably, such a thesis would make interesting reading.

In contrast to the first book *Bird Behavior* by F. B. Kirkman is a mature and thought-provoking study that should find many supporters among serious students of ornithology and comparative psychology. The author has spent years concentrating on the behavior and reactions of the black-headed gull (a British coastal form) and delivers in the present book an excellent summary of his findings. The material is organized as follows: Chapters I-VIII describe the breeding cycle of the gull; Chapters IX-XII compare the difference between the perceptual capacity of this bird with other birds and with men and are based largely on experimental field studies; and Chapters XIII-XVI describe and classify the gull's major emotional reactions. The volume contains an appendix that details many of the experiments performed, has a useful bibliography and index and is embellished by a number of excellent photographs.

HAND BOOK FOR THE CURIOUS.
By Paul G. Howes. G. P. Putnam's Sons, New York. $3.75. 7½ x 5⅝; xix + 364; 1936.

This is not simply another natural history, but a collection that represents the choice of the people themselves. The author, a curator of the Bruce Museum in Connecticut, has covered, as far as possible, those odd and interesting things that the people themselves have found, and wonderingly brought in to him for information. These range from the very lowest sponges and jelly fish through worms, starfish, crustaceans, arachnids, clams, snails and their like to large fish, amphibians, and reptiles. There is even a chapter on first aid in snake bites.

Simply and clearly the author describes hundreds of curious specimens found by the wandering layman in the eastern United States. He gives both their common and technical names; tells us to what group or phylum they belong; what they do; and whether they are harmful or beneficial and are to be protected. The awe inspiring praying mantises; baby fishes "with their bellies bursting out;" the "stunted lobster lost in fresh water pond" and many other strange creatures selected year after year by the curious, are adequately taken account of in this compact little book.

There are many excellent illustrations, a short, selected bibliography and a long and detailed index.

ZOOLOGICA. *Scientific Contributions of the New York Zoological Society. Volume XXI, Part 4, Numbers 19–23.*

New York Zoological Society, New York. 90 cents. 10½ x 7; 72 + 3 plates + 1 folding chart; 1936 (paper).

The articles in this number of *Zoologica* include: The Southwestern Desert Tortoise, *Gopherus agassizii*. By Chapman Grant. Brief observations made on the habits, young and range of this tortoise which tourists are buying as a pet, and a table of external measurements made on 30 adult males and 30 adult females.

Plankton of the Bermuda Oceanographic Expeditions. VII. Siphonophora Taken During the Year 1931. By Captain A. K. Totton. A classification of the siphonophores drawn at definite levels and in a definite area off the south coast of Bermuda.

The Female Bitterling as a Biologic Test Animal for Male Hormone. By Israel S. Kleiner, Abner I. Weisman, Daniel Mishkind and Christopher W. Coates. A summary of various experiments leading the authors to conclude that it is the male hormone in human urine which when added to the water of an aquarium containing female bitterlings, causes the lengthening of the ovipositor of these fishes.

Some Tropical Fishes as Hosts for the Metacercaria of *Clinostomum complanatum* (Rud. 1814) (=*C. marginatum* Rud. 1819). By Ross F. Nigrelli.

Caudal Skeleton of Bermuda Shallow Water Fishes. I. Order Isospondyli: Elopidae, Megalopidae, Albulidae, Clupeidae Dussumieriidae, Engraulidae. By Gloria Hollister. A study of the similarities and differences found in the caudal skeletons of the Bermuda Isospondyli.

CULTURE METHODS FOR INVERTEBRATE ANIMALS. *A Compendium prepared coöperatively by American zoologists under the direction of a committee from Section F of the American Association for the Advancement of Science.*

By Paul S. Galtsoff, Frank E. Lutz, Paul S. Welch, James G. Needham et al. Comstock Publishing Co., Ithaca. $4.00. 9 x 6; xxxii + 590; 1937.

A great deal of experimental biology is dependent upon the successful husbandry of diverse animal forms. This is well attested by the *Drosophila* situation where results, both genetic and otherwise, have accrued largely because this particular species has lent itself to easy culture. There are, however, many other organisms equally suitable for research and equally capable of being kept in the laboratory. Unfortunately, this information has been largely in the hands of a few specialists and not easily available to the investigator. The present compendium, prepared coöperatively by American zoölogists, will do much to remedy this situation for it gives a wealth of useful information on the culture of many invertebrates. The book will prove valuable in a number of ways and is deserving of warm welcome by biologists. The text material is organized on taxonomic lines and the various sections are designed to give practical data on the methods of rearing, handling and observing the form in question. Most of these discussions are of first-rate calibre. The book is well indexed and contains a number of pertinent references.

BAKTERIENFREIE MEERSCHWEINCHEN. *Aufzucht, Lebensfähigkeit und Wachstum, nebst Untersuchungen über das Lymphatische Gewebe.*

By Gösta Glimstedt. Levin and Munksgaard, Copenhagen. Kr. 10. 9¾ x 6½; 295; 1936.

Numerous attempts to rear bacteria-free animals have been made since 1885. The present study is a report of the largest-scale and most significant successful attempt to date, both with reference to number of animals reared and the duration of time lived under bacteria-free conditions. Previous to this study the record was held, for vertebrates, by Küster who in 1911 succeeded in keeping a goat bacteria-free for 12 days from birth, and by Cohendy and Wollman who in 1914 reported the survival of a bacteria-free guinea pig to an age of 18 days.

Glimstedt's experiments were conducted from 1928 to 1936 in the Institute for Chemical Medicine of the University of Lund. Of 57 animals from 22 litters, bacteria-free at birth, eight survived the twenty-eighth day. Of these, three were killed for examination on the twenty-eighth day, two on the thirty-second, and

three on the sixtieth. Comparisons with control animals reared on several different kinds of rations showed that the bacteria-free guinea pigs were inferior to the control groups in rate of growth and in development, in particular that of the lymphatic tissue. The author concludes that the non-pathogenic bacteria normally found in these animals exert a favorable influence upon growth and development.

This is an important book. It is provided with a thirteen-page bibliography but lacks an index.

SNAKES AND THEIR WAYS.

By C. H. Curran and Carl Kauffeld. Harper and Brothers, New York. $3.50. 9¼ x 6¼; xvii + 285 + 32 plates; 1937.

The authors have turned out a fascinating and authoritative book on the natural history of snakes. The first ten chapters deal with the more general biology of snakes, and with snake poisons and the problem of treating snake bites. There are chapters on rattlesnakes, the true vipers, snake-eating snakes, tree snakes, blind snakes, Asiatic cobras, African cobras, boas, anacondas, and fresh water snakes. The deadliest snake in this country is the diamond-back rattlesnake of Texas. While there has always been a considerable element of exaggeration in the accounts of the virulence of snake poisons, the authors readily admit that the black mamba is probably even worse than its reputation and exhibit a healthy respect for the courage of the snake charmers of Asia. The photograph on the dust jacket illustrates the best of the snake charmer tales. Fantastic stories by the legion have been invented about snakes, and some of them are given here. The importance of snakes in history and religion has a short chapter.

There are 22 pages of excellent photographs; a check list of snakes of the United States and Canada; and a general and scientific index.

AN INTRODUCTION TO NEMATOLOGY. *Section 1, Part 1.*

By B. G. Chitwood and M. B. Chitwood. Monumental Printing Co., 3110 Elm Avenue, Baltimore. $2.50. 20 per cent discount on 5 or more copies; 20 per cent discount on orders for all parts. 12 x 9; 53; 1937 (paper).

Many books have appeared that deal with the economic, medical, veterinary, and taxonomic aspects of nematology. To supply the need for a comprehensive treatise on the purely zoological aspect of the subject, the authors have attempted the present work. This brochure is the first of the series of ten numbers which will be published from time to time until the book is completed.

The writers have handled the subject from a comparative standpoint, and for this reason have divided the present book into three sections: anatomic, ontogenetic, and systematic. The morphology of the different nematodes is given in minute detail, and in many cases the description is aided by the use of drawings and diagrams. Each chapter of the book closes with an extensive bibliography on the particular phase of the subject presented in that chapter. The present volume should be useful to the beginner, as well as to the taxonomist, and, to a lesser extent, to those dealing with the experimental phases of nematology.

MARINE FISHES OF SOUTHERN CALIFORNIA.

By Percy S. Barnhart. University of California Press, Berkeley. $4.00. 10 x 7¾; iv + 209; 1937.

This work, by a well known British ichthyologist, now on the staff of the Scripps Institution of Oceanography, consists of a collection of descriptions and illustrations of all species of fish that have ever been reported taken between Point Concepcion and the TiJuana River. There may be a few which the author has overlooked, as he states in his preface, but certainly these are not very many.

It will come as a surprise to many of us to know that one species of lancelet and three of cyclostomes have been taken within these limits, and to learn that there is a sea horse on the west American coast that grows to be twelve inches in length. The large number of eel-like fishes, none of which is a true eel, is also surprising,

as is also the group of needle fishes, which resemble miniature sword fishes except that the needle is in the lower jaw. An innovation is the raising of the elasmobranchs to the rank of a class. The illustrations are well drawn, and there is a glossary, a bibliography, and two indexes.

DAS LEBEN DEUTSCHER GREIFVÖGEL. *Die Umwelt der Raubvögel unter besonderer Berücksichtigung des Habichts Bussards und Wanderfalken.*

By Heinz Brüll. Gustav Fischer, Jena. RM 6. 9½ x 6½; vi + 144 + 1 folding chart; 1937.

The predatory birds native to Germany are grouped variously according to type of area inhabited, senses involved in locating prey, type of beak, mode of attack, prey, enemies, attitude to human beings and other characteristics. The short-flight birds such as the night-hawk, that depend more upon the auditory than visual sense, inhabit the wooded regions. The soaring species, exemplified by the buzzard, whose auditory and visual equipments are both highly developed, are found most often in mixed landscapes, interspersed with wooded lots and fields. The tree falcon and migrating falcon, both long-distance fliers with sight more acute than hearing, are typical of the predatory birds frequenting the open areas. Data are presented on the relative surface area of the wings for the birds discussed, and a bibliography and a glossary of hunting terms are added.

A BOOK OF FAMOUS DOGS.

By Albert P. Terhune. Drawings by Robert L. Dickey. Doubleday, Doran and Co., Garden City, N. Y. $2.75. 8¼ x 5½; 300; 1937.

Here are well retold dozens of your favorite dog stories where you may renew the acquaintance of such old friends as Barry, the greatest of Saint Bernards; Satan, the world hero; and Flush, Elizabeth Barrett Browning's spaniel. You will probably be resentful, though, at the rough handling that Greyfriars Bobby receives in a "debunking" chapter on "professional mourners," for where is sentimentality excusable if not in a tale like this?

The most delightful new friend we made in this book was a black poodle by the name of Schwartz, who every morning crossed the street to a store opposite his master's house in Heidelberg to bring home a pouch of tobacco. After three years of this, Schwartz and his family moved to another city some hundred and fifty miles away and were delighted to find a tobacco store just opposite their new home as before. But Schwartz did not know this. You can guess what happened. His master demanded tobacco. Ten days later an exhausted poodle returned with the bedraggled remains of a pouch from the old store in Heidelberg.

BIRDS OF AN INDIAN GARDEN. *Second Edition Revised and Enlarged.*

By T. Bainbrigge Fletcher and C. M. Inglis. Thacker, Spink and Co., Calcutta. Rs. 12. 9⅞ x 7¼; xii + 201 + 35 plates; 1936.

As there has been no popular book on Indian birds this volume, which first appeared as a series of papers in the *Agricultural Journal of India* during the years 1919 to 1924, is an attempt to familiarize the Indian and European laymen with them. Fletcher gives lengthy descriptions of 33 common Indian birds—the jungle, the town and the garden varieties—and mentions many details concerning their roosting, breeding, nesting, and feeding habits. The popular, as well as scientific, names are used in describing the different species and substantial data collected on them include their parasitic tendencies, their time of migration and expositions of their calls and songs. Many of the descriptions are dry and lack vividness, but here and there the author comes forth with bits of bird life of human interest.

Thirty-three large and brightly colored plates by the co-author together with a collection of 19 black and white drawings sprinkled through the text illustrate the volume. Two plates are added at the end showing the sizes and markings of the eggs of 30 of the birds described. There is neither bibliography nor index.

THE INSECT MAN. *A tale of how the Yew Tree children went to France to hear the story of Jean Henri Fabre in the places where he lived and to see the homes of some of the insects whose life-story he has written.*

By Eleanor Doorly. Introduction by Walter de la Mare. D. Appleton-Century Co., New York. $1.50. $7\frac{7}{8}$ x $5\frac{1}{8}$; xvii + 180; 1937.

The author has written an ingenious little book introducing to English children the life of the French entomologist, Henri Fabre, and his writings about the habits of insects. The theme of the book is a quaint story of how three English children and an older sister "went to France to hear the story of Henri Fabre in the places where he lived, and to see the homes of some of the insects whose life-story he has written."

As Mr. de la Mare says in his introduction, any child of imagination who reads this book will have learned much about Fabre and his work, and "will have won to something at least of his inmost self and spirit." Mr. Gibbings' wood-cuts, whether of insects, buildings, places or things, are an interesting addition to a very pleasant volume.

JUST CATS.

Pictured by Lowes D. Luard and described by T. O. Beachcroft. Country Life, Ltd., London; Charles Scribner's Sons, New York. $3.75. $11\frac{1}{2}$ x $8\frac{1}{2}$; 139; 1936.

A volume of delightful illustrations, reproductions from etchings, pencil studies and pen drawings, depicting all kinds of cats from the torpid, contented cushion and fire-side variety to the taut and lanky alley cat outcast. Although Mr. Beachcroft's text, written around and about the drawings seems at times a bit strung out, perhaps in an effort to pad in between the numerous pictures, in places his characterizations and descriptions are really intriguing.

Alley cats, Siamese cats and tabbies, their origins and the legends that have sprung up around them, as well as their habits, gestures and movements, are simply and realistically described. The author's account of the old episode of our feline friend in pursuit of a sparrow is here given real life and feeling. [It is, though, hell for the sparrow. *Ed.*]

DIE TSETSEFLIEGEN: *Ihre Erkennungsmerkmale, Lebensweise und Bekämpfung. Ein Leitfaden für die Praxis.*

By F. Zumpt. Gustav Fischer, Jena. RM. 9 (paper); RM. 10.50 (cloth). $10\frac{1}{2}$ x $6\frac{3}{4}$; iv + 149; 1936.

This handbook for sanitary officers and research workers in the tsetse infested areas of Africa is the first treatise of its kind in German since the publication in 1905 of Sander's *Die Tseten*. Much more has been learned about these flies since then. For each species the distinctive characteristics and available information on habits, breeding, distribution, density (flies per boy hour), and pathogenicity are discussed. A section of the book is devoted to methods of eradication. The work is abundantly illustrated with schematic drawings, photographs, maps and an excellent colored plate. The bibliography is adequate and there is an index.

REVISTA DI PARASSITOLOGIA. *Publicazione Trimestrale. Volume 1, Number 1, January 1937.*

Edited by A. Missiroli. Redazione e Amministrazione, Via G. B. Martini, 6, Roma. L. 60, Annual Subscription; L. 15, Separate Numbers (in Italy and Colonies); L. 90, Annual Subscription; L. 25, Separate Numbers (outside of Italy). 10 x 7; 87; 1937 (paper).

REVISTA DI PARASSITOLOGIA. *Volume 1, Number 1. Supplemento Monografico N. 1.* Fauna anofelinica delle Colonie italiane, by Lidia La Face.

Edited by A. Missiroli. Redazione e Amministrazione, Via. G. B. Martini, 6, Roma.

This new quarterly, edited by an outstanding malarialogist, is dedicated to the publication of articles on protozoology, helminthology and entomology. The first number contains articles on experimental studies of the biological cycles of *Lepocreadium album* and of *Mesometra orbic-*

ularis (Rud.); on a new species and a new variety of Cercariae discovered in Sardinia, and others. There is a supplement of over 100 pages which presents a comprehensive review of the reports on the kinds of *Anopheles* which inhabit the Italian African colonies. Each of the articles carries English and German summaries.

THE INTERNAL PARASITES AND PARASITIC DISEASES OF SHEEP. *Their Treatment and Control.*

By I. C. Ross and H. McL. Gordon. Angus and Robertson, Sydney. 25s. 8½ x 5½; xx + 238 + 46 plates; 1936.

This monograph deals with problems of the life-history, pathogenicity, treatment and control of the helminth parasites of sheep. The book is admittedly practical in character and is designed primarily to be useful to veterinarians, stock inspectors and sheep owners of Australia. There is little doubt but that it will fulfil its goal in this regard for the material is well-chosen, helpfully organized and clearly presented. The discussions are arranged taxonomically with all the important species considered. For each section data are given about the distribution, life-history, pathogenic importance, symptoms and diagnosis, treatment and prophylaxis for the form in question. The book is illustrated with photographs and drawings and contains a first-rate bibliography, index and glossary.

STRANGE INSECTS AND THEIR STORIES. *How they live. Various kinds and species. Curious traits. Their intelligence. Ways of communicating with each other. Battle for survival. Benefit to all mankind, etc.*

By A. Hyatt Verrill. L. C. Page and Co., Boston. $2.50. 8¾ x 6; xv + 205; + 5 plates; 1937.

Again Mr. Verrill has succeeded in capturing the enchantment of the nature world. In this eminently readable book the author discusses only those insects that the average person might observe and leaves alone the exotic ones from remote corners of the earth. He tells of insects that steal rides, roll a ball, bury the dead, and even of some that fire gas bombs. In a closing chapter he gives a few practical hints to young entomologists on mounting, preserving and breeding insects.

The book is amply illustrated with pen and ink drawings by the author. There is an index.

MORE SONGS OF WILD BIRDS.

By Albert R. Brand. Foreword by Arthur A. Allen. Thomas Nelson and Sons, New York. $2.50. 8¾ x 7½; 116; 1936.

This is the second of a series of books by the same author describing bird songs and calls recorded on three double faced phonograph records included in a folder in the back of the book. The notes of the birds were accurately recorded in the field on sound films. These show that much of the song is pitched far higher than the human ear can perceive. Phonograph records and needles are incapable of faithfully reproducing even the audible notes pitched above the range of the piano and violin so the records are rather disappointing. However, the drawings and descriptions of the birds, and a chapter on the significance of the songs make the book worth having.

AN ACCOUNT OF THE FISHING GEAR OF ENGLAND AND WALES. *Third Edition (Revised, 1936). Fishery Investigations, Series II. Vol. XV, No. 2.*

By F. M. Davis. His Majesty's Stationery Office, London. $1.75. 10⅝ x 7¼; 139; 1937 (paper).

Detailed information is presented in this publication on the making of various types of nets and on the use of nets and other fishing gear as employed in England and Wales. The text is well supplemented with numerous diagrammatic sketches. Since the appearance of the first edition of this work in 1923 the Vigneron-Dahl gear has become the most important trawling apparatus and the sections on this gear have been entirely rewritten in the present volume. Another addition is a chapter dealing with the modificaions of fishing gear, designed to mitigate the ill-effects

of the destruction of small unmarketable fish.

There is an index and a selected bibliography of 129 references.

GUARDIANS OF THE WILD.

By M. B. Williams. Thomas Nelson and Sons, London and New York. 2s. 6d. 7 x 5; x + 148; 1936.

Miss Williams tells the story of the Canadian National Parks, how they came to be started, and what is being done at the present time in the interests of conservation. Large areas of the National Parks, heretofore unexplored, have been made accessible by highways, and tourists have been attracted in such numbers that the Parks have become an important source of revenue to the Canadian government. Wild animals which in the past faced extinction are now increasing in numbers. The book has been designed for popular consumption, but it makes very interesting reading. There are a number of photographic plates.

PHYSIOLOGIE DER SÜSSWASSERFISCHE MITTELEUROPAS. *Handbuch der Binnenfischerei Mitteleuropas, Band II B.*

By Wilhelm Wunder. E. Schweizerbart'sche, Stuttgart. In Germany: 49. marks (paper); 52. marks (cloth). Outside of Germany: 36.75 marks (paper); 39. marks (cloth). 10½ x 7½; xi + 340; 1936.

This comprehensive treatise on the physiology of the fresh-water fishes of Central Europe gives information on the skin, sense organs, nervous system, breathing apparatus, blood, nutrition, excretion, internal secretions, temperature, locomotion, reproduction and embryonic development. In fact, it contains "everything theoretical or practical" which might be of interest to the professional (fisher, research worker, or fishery official), the amateur or the sportsman. It is illustrated, indexed, and each section has a bibliography.

BRITISH GRASSHOPPERS AND THEIR ALLIES. *A Stimulus to their Study.*

By Malcolm Burr. Philip Allan and Co., London. 6s. net. 6½ x 4¼; xvi + 162 + 6 plates; 1936.

In the British Isles there are less than forty species of Orthoptera, using that term in its broader sense. It is therefore possible to cover them all in a book small enough to be carried in the pocket, and have enough space left over for the earwigs. This is a well written work, but it is not in any sense a beginner's book. Its chief merit is its completeness and its compactness; its chief defect is the sparsity of its illustrations, but those which it has are excellent. Its most distinctive feature is a series of maps of the British Isles, showing the geographic distribution by counties of the more important species. There is no index, but such a brief work does not need one.

HOUSEHOLD PESTS: *Their Habits, Prevention and Control.*

By Peter B. Collins. Sir Isaac Pitman and Sons, London; Pitman Publishing Corp., New York. $1.00. 7¼ x 4¾; xiii + 98; 1936.

This work is intended chiefly for the housekeeper, and contains only just enough scientific information to help her to cope intelligently with vermin. In many instances the most effective way of dealing with such unwelcome guests involves the use of poisons which the inexperienced person should not handle, and the merit of the book lies in the fact that it gives so much information on the art of using poison and the necessary precautions to be taken—information that it is sometimes difficult to obtain. The index covers four pages.

HOST-PARASITE RELATIONS IN THE DISTRIBUTION OF PROTOZOA IN TERMITES. *University of California Publications in Zoology, Volume 41, Number 15.*

By Harold Kirby, Jr. University of California Press, Berkeley. 35 cents (with No. 16) 10¼ x 6¾; 25; 1937 (paper).

THE DEVESCOVINID FLAGELLATE PARAJOENIA GRASSII FROM A HAWAIIAN TERMITE. *University of California Publications in Zoology, Volume 41, Number 16.*

By Harold Kirby, Jr., University of California Press, Berkeley. 35 cents (with No. 15) $10\frac{1}{4}$ x $6\frac{3}{4}$; 10; 1937 (paper).

A REVIEW OF THE GENERA CLAUSIDIUM KOSSMANN AND HEMICYCLOPS BOECK (COPEPODA, CYCLOPOIDA), WITH THE DESCRIPTION OF A NEW SPECIES FROM THE NORTHEAST PACIFIC. *University of California Publications in Zoology, Volume 41, No. 14.*

By S. F. Light and Olga Hartman. University of California Press, Berkeley. 25 cents. $10\frac{1}{4}$ x $6\frac{3}{4}$; 18; 1937 (paper).

BOTANY

TREES. *A Pictorial Volume for Lovers of Nature.*

By Thomas O. Sheckell. Frederick A. Stokes Co., New York. $4.00. $9\frac{3}{4}$ x $7\frac{3}{4}$, 176; 1936.

Eighty-two photographs of United States trees from the Atlantic's rocky Maine coast to the Pacific shores of southern California. This is not only a naturalist's collection, it is an artist's as well. While the outlines of the individual trees are clear and beautiful in themselves, the enchanting part of these exceptional photographs lies in their background of typical and illustrative scenery. Here we see the rugged spruce perched high on the Wasatch mountains of Utah, the date palm casting its shade over a trim, tropical Pasadena garden, a gnarled cypress clinging desperately to the rock-bound shore of Monterey, the Pacific roaring at its foot, the old elms looking over the peaceful hayfields and rolling hills of New York state, Lombardy poplars, sentinels to the valley of the Great Salt Lake, with the Oquirrh mountains misty in the distance, and the sturdy pine looking out to sea from the rock-ribbed coast of Maine. The Joshua tree of Nevada is shown standing alone in the desert heat; the dogwood and fine New Jersey apple tree in all their spring blossoms; and winter trees casting their naked shadows on snowy landscapes.

The photographs have not only the beauty of paintings but almost the realness of the outdoors itself. The expressive simplicity of Mr. Scheckell's short captions add a poetic touch to an already beautiful piece of work.

THE STORY BOOK OF FOODS FROM THE FIELD. *Wheat, Corn, Rice and Sugar.*

By Maud and Miska Petersham. John C. Winston Co., Philadelphia. $2.50. $7\frac{3}{4}$ x 8; 128; 1936.

Once upon a time children made friends with fairies and goblins and gnomes and loved Alice dearly. But the self-respecting modern child should, if properly brought up, hold up his hands in horror at such scientific heresies. Rather he should be deeply interested in a learned, though simply expressed, discussion of the virtues of cleaning one's teeth and where the breakfast food comes from. So conditioning a youth is well calculated to produce a properly regimented citizen. We, however, will be so bold as to express the opinion that there is something to be said for the old horse and buggy type of fairy story since we prefer individuals with some little imagination and originality even if they are not quite so thoroughly self-washed behind the ears.

The present book is instructive and carefully accurate. The illustrations are colorful and enjoyable. A great many psychology-conscious parents and maybe a few children will be delighted with it.

THE PRODUCTION OF FIELD CROPS. *A Textbook of Agronomy. Second Edition.*

By T. B. Hutcheson, T. K. Wolfe and M. S. Kipps. McGraw-Hill Book Co., New York. $3.50. 9 x 6; xvii + 445; 1936.

The first edition of this text has been in use since 1923 and the present volume reaps the benefits derived from constructive criticisms and suggestions made by those who have used the first for teaching purposes. The original plan of the book was patterned after an outline for a standard introductory course in field crops, adopted by the American Society of Agronomy. The plan of the revised edition is essentially the same although the size of the volume has been somewhat reduced to fit more nearly the requirements of a one

semester course. The first section of the book is devoted to a discussion of the fundamentals underlying all crop production and the following sections to the production of special crops: cereal or grain crops, legumes for seed, forage crops, root crops, tubers, sugar plants and stimulants. Each chapter of each section is followed by a list of references and topics for discussion. There is an index.

FUNDAMENTALS OF BACTERIOLOGY.

By Martin Frobisher, Jr. W. B. Saunders Co., Philadelphia. $3.25. $7\frac{3}{4}$ x $5\frac{1}{4}$; 474 + 1 folding chart + 4 plates; 1937.

This volume has been prepared especially for students seeking a clear and practical presentation of the facts concerning both pathogenic and non-pathogenic forms of bacteria and their effect on everyday human life and activity.

The text is divided into three parts: I—The Fundamental Principles of Bacteriology; II—The Class Schizomycetes; and III—The Relation of Bacteria to Disease. The use of the microscope, methods of cultivation and staining, and the general morphology of bacteria are presented with an unusual regard for detail. The various classifications of bacteria, the essential facts about them and their practical effect upon food, health, and many classes of industry and agriculture are clearly and precisely described. The many photographs, diagrams, and drawings add considerably to the presentation of a very inclusive assemblage of material. The book boasts an index and a detailed table of contents, which enhance its value as a reference and as a text.

METHODS IN PLANT PHYSIOLOGY. *A Laboratory Manual and Research Handbook. With a Chapter on Statistical Methods, by George W. Snedecor. First Edition.*

By Walter E. Loomis and Charles A. Shull. McGraw-Hill Book Co., New York. $4.50. 9 x 6; xviii + 472; 1937.

The material in this volume has been compiled for use by the instructor, the student, and the research worker in plant physiology. It is divided into two parts, the first consisting of laboratory exercises, and the second of detailed outlines of methods and procedures. The laboratory exercises, though grouped by subject, have been divided into three grades: elementary, intermediate and advanced. In every case the grade is indicated and, in addition, at the end of each exercise there are review questions.

The book has been written for those having only moderate training in physics and chemistry and represents a comprehensive survey of the field of plant physiology. There is a chapter on statistical methods by George W. Snedecor and an appendix containing numerous useful tables of elements, solutions, measurements, etc. There is, besides, an index.

THE ROMANCE OF TEA. *An Outline History of Tea and Tea-Drinking Through Sixteen Hundred Years.*

By William H. Ukers. Alfred A. Knopf, New York and London. $2.75. $8\frac{5}{8}$ x $5\frac{3}{4}$; xiv + 276 + xii; 1936.

In this delightful book the editor of the *Tea and Coffee Trade Journal* narrates the history of tea in China and Japan from the first certain reference to it in the fourth century A.D., and the spread of tea growing to other countries of the Orient and of tea drinking to the Occident. The story of the East India Company and of the clipper ships which later brought the cargoes of tea from China to the West are full of interest. The book also describes the growing and manufacture of tea, gives a statistical résumé of the commerce of tea, and deals with tea manners and customs of Orient and Occident, with the ceramics of tea pots and with allusions to tea in literature. A final chapter gives useful information on the choice and brewing of tea.

A MONOGRAPH ON THE GENUS HEUCHERA. *Minnesota Studies in Plant Science Volume II.*

By C. O. Rosendahl, F. K. Butters and O. Lakela. University of Minnesota Press, Minneapolis. $3.00. $9\frac{3}{8}$ x 6; 180; 1936 (paper).

This exhaustive study of the genus *Heuchera* (of the Saxifrage family) is based on material from the principal herbaria in this country and from one abroad, from botanical centers, and from field and garden. The authors show that the changes in the several characters "can be traced step by step from the more primitive types up to the most highly specialized, and in several instances parallel lines of development occur. It is to be noted, however, that if the majority of species of *Heuchera* were to become extinct and only a few of the more extreme forms were to remain, these would probably be regarded as distinct genera." The volume contains a number of illustrations, is well documented and has an index of the botanical names in the genus.

MORPHOLOGY

RECENT ADVANCES IN CYTOLOGY. *Second Edition.*

By C. D. Darlington. Foreword by J. B. S. Haldane. P. Blakiston's Son and Co., Philadelphia. $6.00. 8 x 5⅛; xvi + 671 + 16 plates; 1937.

The first edition of this book, published in 1932, (*cf.* Q.R.B. Vol. 3, No. 1, p. 107) aroused much controversy and brought forth many objections. J. B. S. Haldane, in the forward to the 2nd edition, says, "However, most of these objections have been quietly withdrawn in the four succeeding years. The most important correction to the views expressed in the first edition has been made by Dr. Darlington himself." The first edition attempted to describe only one aspect of cytology, the study of the nucleus and the chromosomes in plants and animals, and devoted the last chapter to "the evolutionary point of view." Increasing knowledge has made it possible for him, in this edition, to "recast the whole account in terms of evolution" (i.e. showing meiosis as developing from mitosis, etc.) and he has devoted the last chapter to cell mechanics.

The book includes four appendices: interpretation, technique, glossary, and bibliography. The text is copiously illustrated with photographs, diagrams, and tables, and is well indexed.

MAMMALIAN ANATOMY *with Special Reference to the Cat. Sixth Edition.*

By Alvin Davison. Revised by Frank A. Stromsten. P. Blakiston's Son and Co., Philadelphia. $3.00. 8⅜ x 5⅝; xiv + 328; 1937.

The sixth and latest edition of this well-known book has been revised by making a number of minor changes in the text; by enlarging several sections; by adding new and redrawn figures, and by emphasizing comparative material more than was done in previous editions. In the preparation of this volume the authors have kept in mind the fact that an increasing number of students in psychology, education and physical education, as well as those in pre-professional schools, are taking comparative anatomy and have organized their material accordingly. The book possesses a useful glossary and an adequate index. The illustrations are well drafted but the lettering is frequently amateurish. It seems safe to predict that this volume in its latest edition will continue to find friends among students of elementary comparative anatomy.

A MANUAL OF NORMAL HISTOLOGY AND ORGANOGRAPHY. *Seventh Edition, Thoroughly Revised.*

By Charles Hill. W. B. Saunders Co., Philadelphia. $3.50. 7½ x 5; 530 + 6 plates; 1937.

This book is designed for a very elementary course indeed and as such is excellent for organography, being largely a simplified anatomy, but is decidedly lacking in histology. The author feels that "neglect of proper care of the teeth is a common failing" and so devotes a more detailed discussion to them than to any other part of the body. It is intended that the teacher should make up his own laboratory procedure and let it precede the text assignments which he is then to supplement.

It is difficult to see just where such a manual as this finds the considerable array of customers that it must have to reach a seventh edition. It is far too elementary for a medical school course on the one hand, and few undergraduate departments would teach this much human anatomy

on the other. High school teachers of hygiene who wish to obtain a good working idea of the human body should find it admirable.

ANATOMY OF THE FETAL PIG.

By John G. Sinclair. Collegiate Press, Ames, Iowa. $2.00. 9 x 6½; xiv + 80; 1936.

The foetal pig has become in recent years a useful laboratory type in the study of anatomy. This manual aims at a fairly complete study of those structures which should be familiar to a student entering the medical school and elides those which differ so greatly from the human structure that they would not be applicable. Fifty-one illustrations by the author are included in the text which is clearly and concisely written. Teachers of college anatomy will find this an excellent laboratory guide.

VOM BAU UND LEBEN DES GEHIRNS.

By Ernst Scharrer. Julius Springer, Berlin. RM 4.80. 7⅞ x 4⅝; vii + 169; 1936.

Volume 31 of this popular science series concerns the structure and functioning of the brain. The author begins with a brief general description of the nervous system, and then proceeds to discuss in detail the nervous systems of invertebrates, of vertebrates, and finally of man. Subsequent chapters are devoted to the central nervous system, brain and speech, reflexes, and the nervous system as a whole. An excellent little book for the layman.

PHYSIOLOGY AND PATHOLOGY

ELECTRICAL SIGNS OF NERVOUS ACTIVITY.

By Joseph Erlanger and Herbert S. Gasser. University of Pennsylvania Press, Philadelphia; Oxford University Press, London. $3.50. 9 x 5⅝; x + 221; 1937.

This is the third in a series of lectures sponsored by The Johnson Foundation for Research in Medical Physics. It covers the same general ground as the second lecture series given by E. D. Adrian in 1931 on *The Mechanism of Nervous Action*, but enormous advances have been made in this field during the intervening five years. The great difficulty has always been that there was no adequate means of amplifying and graphically recording the extremely weak potentials of the nerve. The old type amplifiers badly distorted the wave formation particularly in low frequencies and would not pick up the weaker potentials at all, while the oscillographs used distorted the form of briefer currents, were kept in adjustment only with much difficulty, and were disturbed by the slightest vibrations in the laboratory. In the last few years, however, the cathode ray oscillograph has been fully developed for physiological use and does away with almost all the former difficulties of recording. The only moving part in this instrument is an electronic beam which has so little inertia that it can faithfully follow electrical oscillations at a frequency as high as 200 million per second. At the same time, due to the recent wonderful improvements made in vacuum tubes, amplification now gives comparatively little difficulty.

As the two authors differ in the interpretation of many points, they decided to divide the lectures each writing those facts of most interest to him. Dr. Erlanger discusses: (1) the analysis of compound action potential of nerve; (2) the comparative physiological characteristics of nerve fibres; and (3) some reactions of nerve fibres to electrical stimulation; while Dr. Gasser discusses (4) sequence of potential changes; and (5) the excitability cycle. Both authors handle their complex material extremely well and we highly recommend the book to workers in other fields who wish to become familiar with this subject without too much work.

CANCER AND DIET. *With Facts and Observations on Related Subjects.*

By Frederick L. Hoffman. Williams & Wilkins Co., Baltimore. $5.00. 9 x 6; xx + 767; 1937.

This book is a comprehensive study of the relation of diet to the cause and control of cancer. It is based largely on questionnaires collected from 2,234 cancerous and

1,149 non-cancerous people that tabulate many diverse data about the food, eating habits and general physique of these 3,383 individuals. The text material is organized around five divisions: (1) dietary theories of cancer; (2) the modern diet; (3) cancer metabolism; (4) dietary facts concerning cancer patients, and (5) general summary and conclusions.

There can be no doubt but that the author has painstakingly and systematically summarized a wealth of material in this volume. To what extent his findings may be supported, either at the moment or at some future date, falls outside the scope of this review. The following selected quotations best summarize the author's opinion relative to the general cancer problem:

> . . . . I have come to the conclusion that the prevailing view that cancer, in its origin, is always a local disease and that treatment should be limited to the local lesion is seriously at fault. It is held, therefore, that without a seriously disturbed derangement of the metabolism the local irritation would be wholly ineffective in producing malignant proliferation. . . . I am absolutely convinced that the underlying cause of cancer is to be found in an excessive intake of foods of a high organic or mineral content, or generally of an alkaline base instead of acid.

The volume has extended bibliographies following the various sections and boasts a good author and subject index. An appendix discusses in detail the questionnaire and is replete with protocols of various sorts.

THE DEVELOPMENT OF MODERN MEDICINE. *An Interpretation of the Social and Scientific Factors Involved.*

By Richard H. Shryock. University of Pennsylvania Press, Philadelphia; Oxford University Press, London. $4.00. 9 x 6; xv + 442 + 8 plates; 1936.

Progress in the art and science of medicine is here viewed in relation to the development of modern civilization. Against the background of scientific and social history, the author presents the major aspects of the evolution of modern medicine. He begins his survey with the 16th and 17th centuries which were to see the first applications of empirical or experimental methods. These were also applied to medicine but in a very limited fashion because theoretical systems continued to prevail. It was not until the 18th century that medicine took another step forward with the teachings and observations of such men as Haller and Morgagni. But the art of healing was still unable to utilize their methods and observations, or those of the empirical sciences. Consequently the public received very little benefit and confronted by such negative results was not inclined to place much reliance in the physician. It was not until the discoveries of the past century which resulted from the application of scientific methods, and the efficient public health measures, all of which have contributed to a striking decline in the morbidity and mortality from certain diseases, that medicine has assumed its high position as a social entity and that medical research has received public support and approval.

This attempt to emphasize the social aspect of medicine is without doubt one of the finest contributions to the study of the history of medicine.

LA PERMÉABILITÉ EN PHYSIOLOGIE ET EN PATHOLOGIE GÉNÉRALE.

By Ernst Gellhorn and Jean Régnier. Masson et Cie, Paris. 160 fr. 10 x 6½; 928; 1936 (paper).

There are few problems of general physiology that do not revolve in one way or another around the question of permeability. It is patent that in studying the dynamics of living cells the biologist must be intimately concerned with the entrance and exit of a variety of substances through the cellular membrane. The present text in French is a comprehensive survey of the permeability problem in both normal and pathological tissues and is a revised and expanded edition of the German volume *Das Permeabilitætsproblem* written by E. Gellhorn in 1929. The text is divided into four major sections: (1) backgrounds for the study of permeability; (2) permeability of cells; (3) permeability of organs, and (4) results and conclusions. The last section is the most interesting one in the book for it discusses critically such problems as the existence of the plasma mem-

brane and the various theories of permeability (the lipoid, colloidal, adsorption and ultra-filtration hypotheses). The book is provided with an excellent table of contents and has an adequate index and bibliography. Without question it is an important contribution to the field of general physiology and will be cordially received by both the student and the investigator.

ANNALES DE PHYSIOLOGIE ET DE PHYSICO-CHIMIE BIOLOGIQUE. *Tome 12, Nombres 2 et 3.*

Edited by L. Lapicque, A. Mayer and P. Portier. Gaston Doin et Cie, Paris. 25 francs for single number; annual subscription for 5 numbers: 120 francs (in France and Colonies); 135 francs (for countries that have a 50 per cent exemption of tariff on periodicals); 150 francs (for other countries). $9\frac{5}{8}$ x 6; No. 1, 169–300; No. 2, 301–524; 1936 (paper).

A series of three articles by E. Le Breton on the physiology of ethyl alcohol oxidation in the body constitutes the most important work published in numbers 2 and 3 of the 12th volume of this journal. These articles report numerous animal experiments made to determine, in particular, the relationship between alcohol concentration in the tissues and speed of oxidation, and the means by which the living organism utilizes alcohol. The results seem to show that alcohol is not a source of body heat nor is it utilized in muscular contractions. Both in rats and rabbits alcohol can be substituted for a considerable portion of other food without appreciable reduction of metabolism. These articles contain also a thorough and critical review of the literature on the subject and detailed descriptions of the experimental techniques.

Other papers in these numbers of the journal discuss individual variation in the nutrition of rabbits; the functions of the carotid sinus and aortic nerves; sex differences; the physico-chemical composition of the blood. The last, a very interesting study, is based on observations made on marine animals.

CONNAIS—TOI OU LA PHYSIOLOGIE SANS PLEURS.

By Henri Coutière. Librairie Polytechnique Ch. Béranger, Paris. 16.50 francs. $6\frac{3}{4}$ x 4; 174; 1936.

The ignorant or even moderately educated layman knows so little about the functioning of his body, and consequently of the proper way to take care of it, that he is often preyed upon by quacks to the point of being reduced to poverty. M. Coutière is of the opinion that this fact is well known the world over, but few if any people try to do anything about it.

In his attempt to remove, in some small measure, the 'evil of ignorance', the author has prepared this small volume on human physiology. It is written in a popular style, and in language readily understandable to every class of people. The chapters are based on the broad organ-systems of the body, but all point toward the integrated functioning of the organism as a whole. The descriptions of the different organs are unique, and are made quite clear by the use of comparisons and analogies. The functions of the different systems of the body and the reactions (chemical, physical, or psychical) are adequately explained without the intricate and tiring detail so frequently associated with physiology texts.

SNOW ON CHOLERA. *Being a Reprint of Two Papers.*

By John Snow, together with A Biographical Memoir by B. W. Richardson, and an Introduction by Wade H. Frost. The Commonwealth Fund, New York; Oxford University Press, London. $2.50. $8\frac{7}{8}$ x $5\frac{1}{2}$; xlviii + viii + 191 + 2 folding maps; 1936.

Dr. Frost considers John Snow's papers on cholera a "nearly perfect model of epidemiology." In a clear, easily understandable style, this eminent Victorian physician and scientist states his reasons for believing that the pollution of drinking water was responsible for widespread epidemics of cholera. Dr. Snow builds up the evidence with minute care and draws his conclusions from hundreds of individual case histories which he has laboriously amassed. Perhaps the most

dramatic proof of his theories came during the terrible Golden Square cholera epidemic, when Dr. Snow persuaded the Board of Guardians of St. James's Parish that if the pump handle were removed from the Broad Street pump, the epidemic would abate. The handle was removed and Dr. Snow was proved correct.

The second paper is entitled *On Continuous Molecular Changes, More Particularly in Their Relation to Epidemic Diseases*. Not the least interesting section of the book is the biographical sketch by Sir Benjamin Ward Richardson, himself a distinguished physician, who pays tribute to John Snow as a representative man of Victorian medicine.

DAS HORMON DES CORPUS LUTEUM (*Biologie, Chemie und Klinik*).

By Erich Fels. Franz Deuticke, Leipzig and Vienna. 12. marks (paper); 14.40 marks (cloth). 10¼ x 7; viii + 169; 1937.

In consideration of the large amount of work that has been published on various aspects of the corpus luteum hormone, this review of the literature and synthesis of the results of biological, chemical and clinical investigations is needed, if for no other reason than as a source of orientation. The author has himself contributed much to the present knowledge of the subject. Beginning with the historical development of the problem in general and a discussion of the test for the corpus luteum hormone, some of the specific aspects treated include: the biological action of the hormone on the uterus, vagina, and symphysis; its influence on the hypophysis and mammary glands; the relationship between ova and corpus luteum, and between the follicle hormone and the corpus luteum hormone; and the therapeutic value of the hormone in the treatment of menstrual disorders, sterility and difficult menopause. Dr. K. H. Slotta of the Instituto Butantan contributes a chapter on the chemistry and synthesis of the corpus luteum hormone. The book is annotated, contains author and subject indices, and is illustrated.

HUMAN PHYSIOLOGY. *A Practical Course. Second Edition.*

By C. G. Douglas and J. G. Priestley. Oxford University Press, New York; The Clarendon Press, Oxford. $4.25. 8¾ x 5⅝; xi + 229; 1937.

This fine text, in its present form, is an account of the practical course in Human Physiology for the Final Honour School in Oxford. It embodies much of the experimental work accomplished by the authors, as well as the newer and better techniques in the field of human physiology. The authors have made no attempt to cover the entire field of human physiology, but have deliberately omitted certain specialized branches, referring the student to texts by specialists in these fields.

The book has a very logical organization, and is written in a clear, straightforward style. The presentation of material gives evidence of much careful selection, alteration, and addition over the older edition. The many diagrams and charts should prove helpful to students using the book as a laboratory manual. The detailed table of contents, the short index, and the many footnote references to more detailed discussions, add substantially to the thoroughness of the volume.

HEALTHY GROWTH. *A Study of the Influence of Health Education on Growth and Development of School Children.*

By Martha C. Hardy and Carolyn H. Hoefer. University of Chicago Press, Chicago. $3.50. 9 x 6; xii + 360; 1936.

This is a report of a series of periodic observations on the health and physical and mental development of about 400 school children of Joliet, Ill. This study, which lasted from 1923 to 1935, had as its main objective to evaluate the effects of an intensive health education program. The children selected were classified into three groups: children who received intensive training, children who participated only in a limited way to the health program, and finally those children who were trained intensively only for a relatively short period. According to the authors, the results demonstrate the effectiveness of the training. Moreover they observed

that good health and good physical development is correlated with higher intelligence and better psychic adjustment. The figures as presented by the authors, however, do not warrant any very definite conclusions. The statistical technique, characterized by excessive faith in the correlation coefficient, is especially inadequate. Nevertheless, a great amount of data is given which will be found useful for other investigators.

RASSE UND KRANKHEIT.

Edited by Johannes Schottky, with articles by various authors. J. F. Lehmanns, Munich. In Germany: 20. marks (paper); 21–60 marks (cloth). Outside Germany: 15. marks (paper); 16.20 marks (cloth). 9¾ x 6½; xv + 468; 1937.

This book attempts to separate the wheat from the chaff in the numerous but sometimes uncritical observations on racial pathology. As Dr. Schottky laments, the anthropologist often knows too little of medicine to diagnose accurately, while on the other hand the physician knows too little of anthropology to give a satisfactory indication of the race of his patients.

After an introductory chapter of definitions and discussion of methodology and a chapter on racial physiology the material is arranged by medical specialties as follows: Internal diseases, infections, tropical diseases, dermatology, neurology, tabes and paresis, psychiatry, surgery, gynecology and obstetrics, ophthalmology, otolaryngology, dentistry, and malignant tumors. A final chapter deals with the effect of race mixture on disease. Bibliographies are appended to the various chapters and there are detailed name and subject indexes.

EXPERIMENTAL AND CLINICAL STUDIES OF THE SPINE OF THE DOG.

By Geoffrey B. Brook. William Wood and Co., Baltimore. $2.00. 8⅜ x 5⅜; ix + 122 + 24 plates; 1936.

A book useful to clinicians in the diagnosis and treatment of diseases of the dog; also to the comparative worker utilizing observations on lower animals in the study and elucidation of disease processes in man. The two parts of the volume deal with: puncture of the *cisterna magna* in the dog (8 sections); and experimental and clinical investigations into the use of iodized oil as a radiopaque medium in the examination of the spinal subarachnoid space of the dog (4 sections). In an appendix is discussed certain features in X-ray photographs of the spine of the dog. Tabular matter and lengthy reference lists are given. The 50 figures (photographic reproductions) are placed at the end of the volume. There is no index.

THE PHYSIOLOGICAL BASIS OF MEDICAL PRACTICE. *A University of Toronto Text in Applied Physiology.*

By Charles H. Best and Norman B. Taylor. William Wood and Co., Baltimore. $10.00. 9 x 6; xxi + 1684; 1937.

The two eminent Canadian physiologists have prepared this textbook to serve the purpose of giving the medical student a clearer view of the physiological changes which take place in disease. The exposition of the subject matter is as follows: (1) blood and lymph; (2) circulation of the blood; (3) respiration; (4) excretion of urine; (5) digestion; (6) metabolism and nutrition; (7) endocrines; (8) nervous system. After a brief description of the anatomy of the organs or systems involved, the experimental data relative to the particular physiological process are presented and discussed with particular reference to information regarding man in health and disease. It is a well written text, clear and comprehensive, and will be found very useful. There is an extensive bibliography of 99 pages.

A STUDY OF THE DIETS OF SIXTY-NINE WORKING CLASS FAMILIES IN NEWCASTLE UPON TYNE.

By J. A. Charles. City and County of Newcastle upon Tyne, Health Department, Newcastle upon Tyne, England. 1s. 9⅝ x 6; 45 + 1 folding table; 1936.

A practical inquiry into the food consumption and expenditure of certain working class families (38 unemployed, 28 employed, 3 widows) during the autumn of 1934. All food stuffs (including all waste as well as food supplied to dogs and cats) were weighed, measured and recorded during the investigation, which lasted a week for each family. Nearly all the members of each family were weighed during the survey and blood haemoglobin was determined in most cases at the end of the study. The data are presented in tabular form. Considerable space is given to a discussion of the nutrient value of the food stuffs consumed by the unemployed as compared with that of the employed, the physical condition of the different members of the two groups of families, etc.

THE PHYSIOLOGY AND PHARMACOLOGY OF THE PITUITARY BODY.

By H. B. Van Dyke. University of Chicago Press, Chicago. $4.50. 9 x 6; xvii + 577; 1936.

The author attempts to describe and evaluate the research done on the pituitary body from 1920–1935, in all its different phases, including physiology, pharmacology and related sciences. Because of the tremendous number of new discoveries that have been made in recent years, particularly in the last decade, there is need for such a book as this which gives a complete, condensed and critical restatement of the work. Chapter I is a description of the anatomy of the pituitary and is followed by chapters on the interrelationship of the hormones of the different parts of the pituitary with other glands and organs of the body, effects of extracts of the various parts of the gland, etc. There is a bibliography listing over 3,000 publications. The author himself consulted some 5,000 articles.

AN INTRODUCTION TO MEDICAL SCIENCE.

By William Boyd. Lea and Febiger, Philadelphia. $3.50. 9½ x 5⅝; 307; 1937.

As the author states, the object of this book is "to give an aeroplane view of disease." Intended primarily for nurses, premedical students and laymen, it is limited to a brief discussion of disease entities and associated pathology. In the first part of the book, the reader is given a general view of human anatomy and physiology, in the second there is a description of the various body organs in health and disease. The third part discusses disease prevention and public health measures. It is a well written book, comprehensive and contains excellent illustrations. The author has achieved his objective and his volume should prove popular.

NUTRITIVE AND THERAPEUTIC VALUES OF THE BANANA. *A Digest of Scientific Literature.*

Research Department, United Fruit Co., Boston. Free. 9¾ x 6⅞; 143; 1936 (paper).

Until the last few years the banana was largely condemned as an indigestible article of food. The tide has turned in recent years, however, and it is now fast becoming highly valued as a source of vitamins and easily digested food and as a direct aid in the correction of various physical ailments. Reasons for this change of thought are brought out by a perusal of this annotated bibliography which presents digests of some 292 articles which have appeared in scientific literature during the last two or three decades showing the results of experimentation and research upon the value of the banana in the daily diet.

HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 460. Abt. V. Methoden zum Studium der Funktionen der einzelnen Organe des tierischen Organismus, Teil 10, Heft 6. Allgemeine und vergleichende Physiologie.* Containing following articles: *Eine Verstärkeranordnung zur Registrierung gehirnelektrischer Spannungen*, by Rudolf Ottenthal; *Neue kataphoretische Verfahren*, by Hugo Theorell; *Lichtelektrische Zellen*

und ihre Anwendung für wissenschaftliche Messungen, by Marie Wreschner.

Urban und Schwarzenberg, Berlin. RM. 9. 10 x 7; 160; 1936 (paper).

These three papers present descriptions of apparatus, directions for its use and examples of application. The first apparatus described is one perfected in the *Institut für elektrische Fernmeldetechnik* in Vienna and is designed for amplifying the electrical potential of brain discharge. The subject of the second paper is cataphoresis, and that of the third, photoelectric cells.

INFANT MORTALITY IN MEMPHIS. *U. S. Department of Labor, Children's Bureau, Publication No. 233.*

By Ella Oppenheimer. Government Printing Office, Washington. 15 cents. $9\frac{1}{4}$ x $5\frac{3}{4}$; vii + 103; 1937 (paper).

In 1932 the infant mortality rate in Memphis, Tenn. was higher than that of any other city of 100,000 or more population. In 1933 and 1934 it continued to increase and a study of the situation was requested. U. S. Census statistics and local studies were analyzed. In this report the possible and probable causes are discussed and recommendations suggested for remedying the existing conditions. It is interesting to note that already a beginning has been made with the appointment of a Director of Maternal and Infant Hygiene in the Memphis Department of Health.

EXPERIMENTAL PHYSIOLOGY.

By George H. Bell. John Smith and Son, Ltd., Glasgow. 4s. 6d. net. 9 x 7; 70; 1937.

This is a laboratory manual designed for an elementary course in medical schools. The directions are all very explicit requiring little added instruction by the teacher, who may therefore handle a rather large class without assistance. No explanations are given of phenomena to be observed, blank pages being left for the student to fill this in for himself. As almost no preliminary knowledge is required on the part of the student and little expensive apparatus is called for, we would recommend the use of this book in a college course for premedical students though a few of the demonstrations might have to be omitted for lack of equipment.

NOTES ON CLINICAL LABORATORY METHODS. *Third Edition.*

Standing Committee on Laboratory Methods, University of Glasgow. John Smith and Son, Ltd., Glasgow. 2s. net. $7\frac{1}{4}$ x $4\frac{3}{4}$; 86; 1936.

The purpose of this little book, issued under the direction of a committee of twelve representing the General Hospitals and University of Glasgow, is to secure uniformity of the laboratory methods in the teaching of clinical medicine in hospital wards. The field covered "is equivalent to side-room testing as usually carried out by students of medicine, together with further tests introduced with a view to completeness." A number of figures and tables are included in the text and there is an excellent index.

HORMONE.

By H. Giersberg. Julius Springer, Berlin. RM 4.80. $7\frac{1}{8}$ x $4\frac{5}{8}$; vi + 169; 1936.

This little book on hormones, No. 32 of a series of scientific publications for the layman, contains much that is interesting about endocrine glands for the general reader. The author starts with a discussion of the thyroid, about which most is known and where the lack or excess of the specific hormone is most spectacular. Subsequently he discusses parathyroids, adrenals, pancreas, pineal and thymus glands, gonads, pituitary gland, hormones and vitamines, hormones among the invertebrates, plant hormones, and a final general chapter on the characteristics of hormones.

WEGE DER SEUCHEN. *Lebensgemeinschaft, Kultur, Boden und Klima als Grundlagen von Epidemien. Unter Berücksichtigung der Tropenkrankheiten dargestellt.*

By E. Martini. Ferdinand Enke, Stuttgart. RM. 6. (foreign countries 25 percent less). 10 x 6¼; vi + 109; 1936 (paper).

The influences of culture, soil and climate on the origin and course of epidemics are treated first separately and then in interrelation with each other. Examples are drawn from all parts of the world but special emphasis is placed on tropical diseases, both animal and human. The first chapter discusses briefly typical life cycles of parasites and bacteria, grouped by modes of transference of infection. Statistical methods of analysis and prediction are presented in an appendix. There is an index.

La Santé Publique et la Collectivité. *Hygiène et Service Social, Coordination. Rapport général de la Commission d'Hygiène de la IIIe Conférence du Service Social, Londres, juillet 1936.*

By Henri Sellier and R. H. Hazemann. Ministère de la Santé Publique, Bruxelles. 8¾ x 6; 72; 1936.

The Minister of Public Health and Physical Education of France and the chief of his technical cabinet outline the aims of public health, its present organisation and its effects. The benefits of centralised administration are stressed, particularly for long-range national planning. Social hygiene is shown not to encroach upon individual rights, but rather to insure them, through euthenic means of wide application.

Alters-Forschung. *Untersuchungen und Berichte über Lebensdauer, Altern und Tod. 3. Jahrgang.*

Edited by Josef Kluger. Josef Kluger, Gartenstrasse 135, Wünschelburg-Heuscheuer. RM. 3. 9¼ x 6½; 40; 1937 (paper).

The third volume of this journal devoted to research in longevity contains two articles about old age in plants and trees, with special reference to the *Affenbrotbaum*. More than half of the journal is taken up with a bibliography of various phases of longevity of the articles appearing in 1935—36 and some from 1934. The more important works are reviewed briefly.

BIOCHEMISTRY

Prelude to Chemistry. *An Outline of Alchemy, its Literature and Relationships.*

By John Read. Macmillan Co., New York. $5.00. 9¼ x 6; xxiv + 328; 1936.

Dr. Read here presents a very careful and scholarly volume on the history, literature, and underlying idea of alchemy from the earliest Egyptian and Chinese origins until the final sounding of its death knell by Lavoisier. Beginning apparently with the practical metallurgical arts, mysticism soon overshadowed experimental evidence, and the basic metaphysical principals which dominated alchemical philosophy until the very end were well established before the Christian era. The extravagant writings of the late renaissance period show little originality of thought, all harking back to the ancient sulphur-mercury theory in their directions for proceeding with the "Great Work" of preparing the philosophers stone, while giving free rein to most lively imaginations in their allegorical descriptions and in their claims of magical power. The present volume is profusely illustrated with reproductions of original engravings and is largely devoted to a discussion of their significance. Unfortunately, little is said of the actual procedures used by the alchemists aside from what they themselves tell in guarded language. The bibliography is extensive and there is a glossary.

An Introduction to Comparative Biochemistry.

By Ernest Baldwin. Foreword by Sir Frederick G. Hopkins. University Press, Cambridge; The Macmillan Co., New York. $1.50. 7¼ x 5; xviii + 112; 1937.

The comparative point of view in any scientific study is always an illuminating approach. In such fields as anatomy, embryology and physiology it has become accepted as commonplace but this has not lessened its value. In biochemistry, how-

ever, emphasis in the past has been placed largely on particular kinds of animals and no great attempt has been made to compare, for example, the fundamental chemical reactions of invertebrate with vertebrate organisms. The present book, although short, makes an interesting start in this direction and is deserving of commendation for this reason. The author prepared the book (1) to serve as a text for students taking elementary biochemistry and (2) to provide a starting point for those who "may find themselves attracted to the subject." The material is both well chosen and clearly presented and covers such topics as the ionic composition of the blood, the regulation of osmotic pressure, nitrogen metabolism, respiration processes, pigments, etc. The book has an index and bibliography and is modestly illustrated. There is a complimentary "Foreword" by Sir Frederick Gowland Hopkins, F. R. S.

PRACTICAL PHYSIOLOGICAL CHEMISTRY FOR MEDICAL STUDENTS.

By G. M. Wishart, D. P. Cuthbertson and J. W. Chambers. John Smith and Son, Ltd., Glasgow. 3s. 6d. net. 7 x 4¾; 127; 1936 (paper).

Even when a laboratory manual is written for use with a particular text book, the experimental work of a course is apt to get quite out of line with the current lectures and text assignments. This book meets that difficulty by combining a laboratory manual with a text book. The union seems to be a happy one. It is designed for a 40 hour course with a large class and a small teaching staff. Both the theoretical discussions and the experimental instructions are written clearly and simply in a rather non-technical language so little preliminary knowledge is required on the part of the student. The subject matter is confined to points of the most direct interest to practitioners, so does not go deeply into theoretical chemistry. We consider it rather unfortunate, however, that absolutely no references are given. For convenience in taking lecture and laboratory notes one side of each page is blank. A rather serious handicap for a book to be used in the laboratory is the fact that the paper cover is not sewn on and has already half fallen off of our slightly handled review copy.

MANUAL OF BIOLOGICAL ASSAYING.

By James C. Munch. J. B. Lippincott Co., Philadelphia. $2.00. 11 x 8½; 179; 1937.

This book, organized on the laboratory outline plan, attempts to summarize a number of techniques of interest to the experimental biologist, pharmacologist, and clinician. Biological assays are defined as "tests of potency of drug products conducted upon intact living animals, or upon surviving isolated tissues." The author discusses such specific assays as anthelmintics, antisyphilitics, insecticides, vitamins, thyroid extracts, etc. Each discussion gives, where possible, information on the physiological action, assay procedure, potency and reference standard of the drug in question. A number of blank forms are included to facilitate the recording of actual results. The book has a good bibliography and an index and should prove useful to workers requiring the detailed knowledge it provides.

CHEMISTRY OF FOOD AND NUTRITION. *Fifth Edition Completely Rewritten.*

By Henry C. Sherman. The Macmillan Co., New York. $3.00. 7¾ x 5¼; x + 640; 1937.

The fifth edition of this book has been completely rewritten in order to include the recent important advances made by research work in the chemistry of food and nutrition. An excellent text for college classes and a sound reference book. The volume is well documented and indexed.

QUARTERLY BULLETIN OF THE HEALTH ORGANISATION. *Special Number, November 1936. Biological Standardisation, II.*

League of Nations, Geneva. Columbia University Press, New York. 65 cents. 9½ x 6¼; 175; 1936 (paper).

This report brings up to date the extremely valuable work of the Commission on Biological Standardisation. By far the largest part of the report is devoted to insulin, eleven papers being presented on this subject.

SEX

THE CHARACTER, CAUSE, AND CURE OF HIGH SCHOOL IMMORALITY (*Syllabus*).
By Teunis Oldenburg. Calvin Press, Grand Rapids, Mich. 35 cents. 7 x 5 + 48; 1936 (paper).

The author regards "every form of unnatural sex behavior as a sin" and believes that "sex perversion antedates Society and was . . . inherited from our first parents through the Fall in Paradise."

With this point of view, a program of educational legislation, censorship and discipline is proposed. The school would return to orthodoxy. Teaching personnel would be carefully selected and supervised on a moral basis, completely masculised except for kindergarten and domestic science. Mixed company in High School clubs would be tolerated only during the daytime and under strict supervision; evening parties and all automobiling forbidden. Sexology would be relegated to parent-teacher societies, and advice therein given by "a Christian physician or a well-informed clergyman."

[Reginald, the Office Boy, was pretty scornful about this *opus*. "Anybody ought to know that it is a lot easier to prohibit alcohol than hormones, and look where we got prohibiting alcohol! What they ought to do is make Casanova and the Decameron required reading in high school," was his wicked and subversive comment.]

ON YOUR GUARD! *The Prevention and Treatment of Sex Diseases.*
By Carl Warren. Foreword by M. J. Exner. Emerson Books, New York. $1.00. 5¼ x 7⅝; xvii + 160; 1937.

This little book is, in the words of the author, "a discussion of personal health aimed to be at once frank, practical and scientifically accurate." The greater part of the material had originally been published as a series of articles, written by Mr. Warren for the New York *Daily News*. There are separate chapters on the history of venereal diseases, symptoms and treatment of syphilis, and of gonorrhea, prophylaxis, and on the cost to society of venereal infection. Since the book was written for the layman, every effort has been expended to make the account as clear and non-technical as possible. Sensational statements of any sort have been scrupulously avoided, and nowhere in the text can we recall having come across a single moral judgment. There is a two page index.

A TEST FOR MEASURING SEXUAL EXCITABILITY IN THE FEMALE RAT. *Comparative Psychology Monographs, Volume 14, Number 1, Serial Number 67.*
By Josephine Ball. The Johns Hopkins Press, Baltimore. $.75. 10 x 6¾; 37; 1937 (paper).

This paper describes in detail a method of testing and rating the sexual excitability of female rats (reliability coefficient .94). It also gives "results of investigations of normal reactions, including a more detailed and extensive study than has been reported heretofore of the exact relations of sexual excitability to vaginal changes as determined by smears, individual differences in excitability and the consistency of behavior from one cycle to the next in the same individual." Graphs and tables are included in the test and there is a list of 17 references.

THE INTIMATE SIDE OF A WOMAN'S LIFE.
By Leona W. Chalmers. Foreword by Winfield S. Pugh. Illustrated by Frank H. Netter. Pioneer Publications, Inc., New York. $1.50. 8 x 5¼; 128; 1937.

The author, a lay woman, has gathered her subject matter apparently from extensive reading of reliable authorities. The thesis of the book is "keep clean," and the main body of the book is taken up with extremely minute information about the

technique of keeping clean. There is no index.

BIRTH CONTROL FOR SAINTS AND SINNERS. *A Critical Consideration of the Birth Control Movement as Influenced by Science and Revelation.*

By Teunis Oldenburger. Calvin Press, Grand Rapids, Mich. $2.50. 7¾ x 5¼; xx + 330; 1934.

In the Gospel according to Teunis Oldenburger it is written that birth control is against God's will. Which of course settles the question. In reading such books as this we always wonder how the authors managed to install a private wire to heaven.

BIOMETRY

DER GEBURTSTOD (*Mutter und Kind*).

By Sigismund Peller. Franz Deuticke, Leipzig and Vienna. 9¾ x 6½; vii + 110; 1936 (paper).

This remarkable little book presents a thorough review and discussion of post-war research on the mortalities of infancy, childhood and maternity, mostly in Europe and particularly in Germany and Austria where so many such studies were produced up to the advent of fascism. Much of the original work is the author's own. The general aim is to show that the death rates of well-developed and normal infants and mothers is connected less with the "skill" of gynecologists, medical techniques and health officers than with various economic and social conditions, many of which are far from clear.

The most striking evidences for this thesis are drawn from such facts as (1) The marked increase in infant mortality, especially of the first two days of life, in most districts of Central Europe during the first four years after the war- the "post-war hunger period. "(2) The universally higher mortality rates of illegitimates, which was especially marked during this period. (3) The rapid diminution of death rates which followed returns to moderate prosperity. This was most striking in England. (4) Marked correlations between mortalities and social-economic levels as determined by a number of criteria, principally occupational. (5) The much lower mortalities of mother and infant when the former retires from working during the last two or three months before delivery. The universally low rates of Jews may be partially explained by this and similar folk customs.

Many other factors are analysed in connection with variation in mortality rates: race and nationality, constitution, urban versus rural habitat, size of family, parity, particular month of birth, general mortality rate and special morbidity rates of the locality, prevailing medical facilities, religious affiliation, and others. These are shown on the whole to be subordinate to those factors which come under the general heading of "Social Hygiene". New data are quoted on partial correlations between social factors and mortality, which confirm this. Local variations in the regulations for recording vital statistics which may lead to error of interpretation are noted. Fewer data are presented on mothers' mortalities than on infants'. But the analysis is as thorough, and the conclusions similar. Unfortunately the book has no index or tabulation of references.

WORLD STATISTICS OF ALIENS. *A Comparative Study of Census Returns 1910–1920–1930. Studies and Reports Series O (Migration) No. 6.*

International Labour Office, Geneva. International Labour Office (Washington Branch), Washington, D. C. $2.75. 9½ x 6¼; vii + 251; 1936 (paper).

In making a critical examination of the data of these eight international tables of alien statistics, one should keep in mind some of the difficulties involved in their compilation, as for instance, the fact that the dates of censuses do not correspond and that the term "alien" has a different interpretation among the different countries and sometimes even in the same country at different times—being classified variously according to political nationality, country of birth, or by race.

Tables I through V list aliens by na-

tionality both by absolute figures and by percentages for countries or territories of Africa, America, Asia, Europe and Oceania. Table VI:—Nationals resident abroad in 1910, 1920 and 1930, by continent. Absolute figures and percentages of world total of all nationals resident abroad. Table VII:—Nationals resident abroad in 1930, by country—as percentages of world total of each nationality resident abroad. Table VIII:—Nationals of European countries resident in other European countries in 1930—as percentages of the total number of each nationality resident in other European countries. There are four introductory chapters, 67 pages of explanatory notes and an appendix with miscellaneous tables concerning alien distribution in years prior to 1910.

GAME FISH RECORDS.

By Jock Scott. H. F. and G. Witherby, Ltd., London. 12s. 6d. $8\frac{3}{4}$ x $5\frac{1}{2}$; xii + 316; 1936.

Interesting statistics can be reported and interpreted on the subject of game fishing with no mention of probable error. The present book presents the largest known sizes of various game fish, including time and place and name of the catcher; casting records; and assorted records of performance, both human and piscine. Principally concerned with Great Britain, it also gives one chapter apiece to Canada, South Africa, New Zealand and Tasmania, United States, and Northwestern Europe. The anecdotes are illustrated with photographs and cartoons from "Punch".

ANTHROPOMETRY OF THE NATIVES OF ARNHEM LAND AND THE AUSTRALIAN RACE PROBLEM. *Peabody Museum of American Archaeology and Ethnology, Harvard University, Vol. XVI, No. 1.*

By W. W. Howells. Data collected by W. L. Warner. Peabody Museum of Archaeology and Ethnology, Cambridge. $1.00. $9\frac{5}{8}$ x $6\frac{1}{4}$; viii + 97; 1937 (paper).

The measurements on which this analysis is based include 239 adult male northern Australian aborigines and 69 females. These differ little in physical type from aborigines of other parts of Australia. The author concludes with Sir Arthur Keith that the Australian is not a blend but a major race which represents an earlier stage in the development of *Homo sapiens* than does any other existing race.

PSYCHOLOGY AND BEHAVIOR

PSYCHOLOGY AND THE SOCIAL ORDER. *An Introduction to the Dynamic Study of Social Fields.*

By J. F. Brown. McGraw-Hill Book Co., New York. $3.50. 9 x 6; xiv + 529; 1936.

This book deals with the methods and principles which underly the application of *Gestalt* psychology to the study of sociology. The subject matter is presented in four sections: methodology, sociology, psychology, and political science. In the first, the author discusses the advantages of the organismic as opposed to the vitalistic and mechanistic theories. From it he proceeds to build the logical construction of the field theory which is founded on "organismic philosophy, hypothetico-deductive methods and language of constructs." In the following sections he discusses problems of race, religion, personality, psychoanalysis, fascism, communism, etc.

The author's forceful and well written presentation of this subject will arouse the admiration of the reader. This treatise stands far above the majority of similar works so that one is tempted to overlook some of the defects inherent in the theory and in the author's viewpoint. These are examples of two fallacies. First, that the treatment of social science is "scientific" as long as geometric symbols are used in the exposition. Second, that since "there is no such thing as human nature independent of the structure of the social field" one need only study the environment and forget completely that also there is no structure of the social field independent of human nature. Most remarkable of all is the author's belief that fascist dictatorship is different from communist dictatorship simply because in one the leaders belong to a class labelled bour-

geois, while in the others they label themselves proletarian.

PSYCHOMETRIC METHODS.

By J. P. Guilford. McGraw-Hill Book Co., New York. $4.50. 9 x 6; xvi + 566; 1936.

"The primary aim of this volume is to teach the student of psychology how to deal effectively and intelligently with quantitative data." The first of its three parts concerns statistical methods as applied to experimental psychology, in particular to the psychophysical methods. Two chapters of introduction to general statistics are included here. The second part concerns psychological scaling methods. The third part on correlation and test methods has five chapters as follows: The elements of curve fitting; Simple correlation methods; Multiple and partial correlation; Mental-test methods; Factor analysis.

An enormous range of topics is covered, thoroughly and systematically with a wealth of illustrative material and examples which include some of the latest of researches. Little statistical theory is presented, but the application of methods is presented with great detail and systematisation. Important formulas are given serial numbers: they total 235, not including alternatives. A helpful list of problems and exercises follows each chapter. Author and subject index are given, also an appendix of 14 useful tables of figures (36 pages).

The book represents at once a most ambitious achievement in itself, and a milestone of the recent achievements in its own wide field. It should prove invaluable in college teaching for many years.

CONTROLLING HUMAN BEHAVIOR. *A First Book in Psychology for College Students.*

By Daniel Starch, Hazel M. Stanton, Wilhelmine Koerth, assisted by Roger A. Barton. The Macmillan Co., New York. $2.50. 8½ x 5½; xiv + 638; 1936.

This work is the organized, practical advice of three social psychologists in several fields of personal adjustment. "It is designed to deal with problems connected with making a living, with establishing and maintaining family life, with behavior in business operations, with influencing people in the mass, and finally with the art of effective, satisfying living."

Part I, on controlling the behavior of self, considers the topics: habit formation, learning and study, efficient thinking, memory, concentration, efficiency in the mobilisation of energy, control of emotions and feelings, adaptations to various social groups, selection of vocation, and "behavior hygiene." While the treatment is laborious and the scientific basis not always clear, a great many valuable suggestions are made, from which few persons would fail to derive profit.

Part II, on controlling the behavior of others, is more frequently open to challenge and of less obvious merit, excepting the first chapters which concern children. Other chapters discuss vocational direction, abnormal persons, commercial advertising, public speaking, music and art and entertainment, propaganda, and religion.

A vast amount of material is presented, in great detail and unabstrusely, even if not always convincingly. With a base which extends over broad fields of biology, anthropology, sociology and economics, however, it is impossible to avoid some points which are highly controversial.

BIOLOGY AND HUMAN BEHAVIOR.

By Mark Graubard. Tomorrow, Publishers, New York. $2.50. 7¾ x 5½; 413; 1936.

The first seven chapters of this book constitute a well written outline of elementary biology with particular emphasis on the study of tropisms and genetics. In the remaining chapters, two in number, the author presents his ideas on the relationship between biological facts and sociological theories. He contends that the sociology of Marx and Engels is the "only complete and scientific" realization of the biological phenomena which underly social behavior. His arguments are too complex to be summarized. It is sufficient

to note that he concludes that social differences between individuals are essentially a product of the environment and not of any innate biological variation; capitalistic society has conditioned man towards evil and crime; if all had equal opportunities this would be an earthly paradise; and so on. All good old Marxist beliefs.

PSYCHOLOGICAL STUDIES OF HUMAN VARIABILITY. *Psychological Monographs Number 212. Dodge Commemorative Number. Edited by Walter R. Miles. Psychological Review Company, Princeton and Albany.* $4.50. $9\frac{3}{4} \times 6\frac{1}{2}$; xxx + 415; 1936 (paper).

This Dodge Commemorative volume of Psychological Monographs is a composite publication of the works of many devoted friends and students of Professor Raymond Dodge. The preface contains an account of his life and contributions to psychology and to the Institute of Human Relations. There are four chapters dealing respectively with experimental studies on children, experimental studies on adults, experimental studies on visual functions, and historical and theoretical studies. A wide range of topics is covered, from such things for instance as age and job satisfaction, to highly complicated researches on vision.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

THE BELLY BOOK *or Diner's Guide. By C. Louis Leipoldt. Williams and Norgate, London.* 7s. 6d. net. $7\frac{1}{4}$ x $4\frac{3}{4}$; xx + 298; 1936.

This thorough-going treatise is a review, with a new title, of a book that appeared over a quarter of a century ago. The author is a medical man, of good taste gastronomically speaking, as well as good judgment scientifically. The book is replete with dietetic common sense. He blows up food fads and fallacies—including some very orthodox ones—with a succession of resounding bangs.

The chapter on the art of dining is a major contribution to aesthetics. It contains among other things, a series of menus, with comments by the author. One of these we cannot forbear quoting, just to make the mouths of lustier zoologists water:

Family Dinner in Trinidad

Mangrove oysters served on ice with pepper-vinegar and limes
Purée of lentils with toasted bread
Boiled red snapper with mayonnaise sauce
Blue crab farci
Stewed lappe served with akee
Avacado salad
Morocoy with pigeon peas
Coconut ice
Guava preserve with cream
Dessert
Cheese
Coffee Liqueurs

The mangrove oyster is one of the finest of the oyster class, and is brought in direct from the swamps with the bivalves still clinging to the root, and opened fresh for the table. The pepper-vinegar must also be freshly made. The blue crab is a species of land crab which needs special preparation. The crabs are kept in a "crabbery" which is attached to the kitchen, and are fed on a special diet in which capsicums enter largely. At the end of a month they are fit for the table. The crab is boiled and the flesh from its big claws and legs carefully removed, the shells being kept. This flesh is then fried, after being mixed with breadcrumbs and spices, and the farci thus prepared is replaced in the empty shell, in which it is served up. Lappe is the Creole name for the pacca (*Cœlogenys paca*), a species of *agouti*, which is one of the most succulent morsels of game that any gourmand can wish for. Akee is the boiled fruit of *Blighai sapida*, and is an excellent vegetable to accompany the game dish when plainly boiled in milk. Morocoy is a land-tortoise (the Brazilian tortoise, *Testudo tabulata*), the preparation of which is very elaborate, since it must be stewed in Bordeaux wine with spices. The liver of this animal is highly esteemed and surpasses in flavour the best qualities of *foie gras*. Pigeon peas are derived from an Indian shrub, and replace in Trinidad the ordinary new peas. Coconut ice as prepared in the West Indies is a delicacy which no one who has only tasted the imitations made on this side of the Atlantic can presume to know the full value of. It is prepared from the milk and jelly found in the tender young nut, which are boiled and mixed with cream and then slowly frozen. Guava preserve is obtainable in England, and, served with cream, is an admirable dessert dish. The cheese figuring on this menu is the flaky *queso de mano* which comes from Venezuela, and which has a mild and agreeable flavour.

The book has a long and interesting bibliography, and is thoroughly indexed. We strongly recommend this treatise to all and sundry.

THE WORLD OF SCIENCE.

By F. Sherwood Taylor. Reynal and Hitchcock, New York. $3.75. 9 x 5⅛; xvi + 1064 + 48 plates; 1937.

Shortly after the appearance of H. G. Wells' *Outline of History* the literary world was flooded with imitative outlines of various things—art, science, literature, religion, among them. Most of these showed signs of having been very hurriedly assembled, and practically all were distinctly inferior to their prototype.

It is unfortunate that Dr. Taylor did not contribute to this series a volume or two dealing with science, for he would have done it admirably, if the present volume is any indication. Like a true outline, it covers the diverse fields of physics, astronomy, geology, chemistry, and biology, in such a way as to make clear that which they have in common and the way in which they contribute to each other. The material is so logically arranged that the narrative appears continuous, and there is a mine of information about the theories of Rutherford, Planck, and Jeans, that will be found most helpful by those who have been brought up on the classical physics of Galileo, Newton, and Laplace.

For obvious reasons the author has omitted the sciences of mathematics and psychology, which seems a wise decision. There is an index of thirteen pages and a list of acknowledgments of five, which latter seems to indicate that the author has left no stone unturned in his search for coöperation in producing a readable book.

THE LEICA MANUAL. *A Manual for the Amateur and Professional Covering the Entire Field of Leica Photography.*

By Willard D. Morgan, Henry M. Lester and Contributors. Morgan and Lester, New York. $4.00. 8 x 5½; 484; 1937.

Probably most minature camera users have little or no idea of the vast possibilities of their cameras. To them and to other amateur photographers this extremely informative book will prove most revealing. Although the material pertains specifically to the Leica camera, it can, with the exception of a few special instances, be applied equally as well to other similar miniature cameras.

The volume contains detailed information about equipment as well as about technique of taking, developing, printing and enlarging the photographs. In addition, there are chapters devoted to special types of photography (such as dental, ophthalmic, microscopic, and aerial) which indicate the possibilities of such a camera for use by biologists, geographers, etc. The editors have done an excellent piece of work and the answer to practically any question on the subject, which is at present answerable, can be found in this book. The text is illustrated with a large and varied assortment of photographs, and there is a detailed index.

NATURWISSENSCHAFTLICHE ERKENNTNIS UND IHRE METHODEN.

By M. Hartmann and W. Gerlach. Julius Springer, Berlin. RM. 2.40. 8¾ x 5½; iv + 70; 1937 (paper).

These two provocative essays, *Wesen und Wege der biologischen Erkenntnis*, by Max Hartmann and *Theorie und Experiment in der exakten Wissenschaft*, by Walther Gerlach, were originally presented as lectures at the 1936 meetings in Dresden of the *Gesellschaft Deutscher Naturforscher und Ärzte*. The first treats the biological sciences, with illustrative examples taken mainly from genetics; the second has physics for a subject. They are printed together here because of the similarity in viewpoint as to the relative positions of deductive and inductive reasoning in scientific research and philosophy. Both emphasize intensive and extensive collection of data and synthesis with results on the same problem obtained from other sciences.